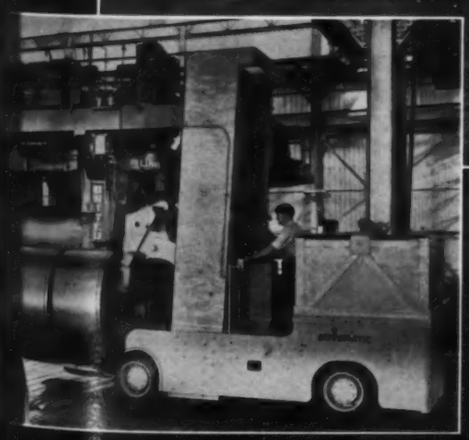
Iron AND Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

1010 EMPIRE BLDG. TECHNOLOGY DEPT. FEBRUARY, 1942 PITTSBURGH, PA.

FEB 25 1942



LEADING STEEL MILLS ARE USING "AUTOMATIC" SHEET HANDLERS AND COIL TRACTORS

For greatest flexibility and ease of handling their sheet and coils from 18,000 to 30,000 lbs.

AUTOMATIC TRANSPORTATION COMPANY

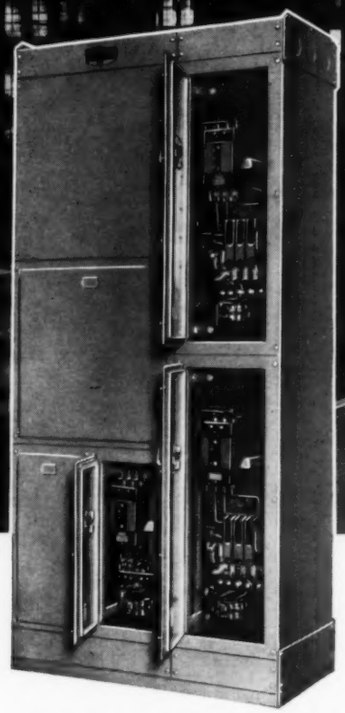
DIV. OF THE YALE & TOWNE MFG. CO.

47 W. 87th Street Chicago, Illinois

TRADE **AUTOMATIC** MARK

COIL TRACTORS SHEET HANDLERS

3 Facts of Vital Importance to Production Today



With every moment of time, every foot of production space, every work unit of manpower of such vital importance, look to Unitrol to wipe out the problem of handling, housing and using Motor Control.

1 Unitrol simplifies and speeds up the installation of Motor Control whether *inside* a machine, *beside* a machine or in a control center serving an entire plant or department.

2 Unitrol simplifies and speeds up the addition, change, replacement and servicing of Motor Control. It makes control always easily accessible . . . separates control from machine, maintenance from production. It keeps control abreast of changing needs.

3 Unitrol cuts down the space required by Motor Control . . . enables you to get more than double the amount of control in the same space . . . may even make plant extensions unnecessary.

The complete Unitrol story is told in the book "Unitrol . . . the next step forward in Motor Control progress." It's yours for the asking. But send for it *today*. CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee, Wis. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto.

1892-1942 50th ANNIVERSARY

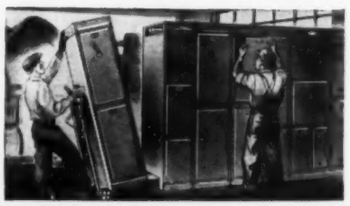
CUTLER-HAMMER
UNITROL
C-H

Copyright, 1942, Cutler-Hammer, Inc.

Unitrol is a *better* method of mounting, housing and *centralizing* Motor Control . . . from the individual unit up to the complete plant-serving motor control center. It is made up from standardized interchangeable parts. It is complete and usable at every step of the way. It is inexpensive, speedy and easy to install, demount or change. It is as "flexible as a rubber band."

The individual Unitrol *Section* houses Motor Control for several motors or motorized machines, is compact, space-saving, convenient and economical. No supports, no other structures or preparation necessary.

The individual Unitrol mounting frame is *better* for machines with built-in Motor Control. It eliminates many machining, wiring and assembling operations.



The complete Unitrol Control Center houses all the control and control equipment in the plant, for easy, speedy man-power-saving installation, maintenance, change, expansion or curtailment. No wall or floor preparation. No racks, trellises or frames. Permits installation of more than double as much control in same space.

BRINGING VICTORY CLOSER

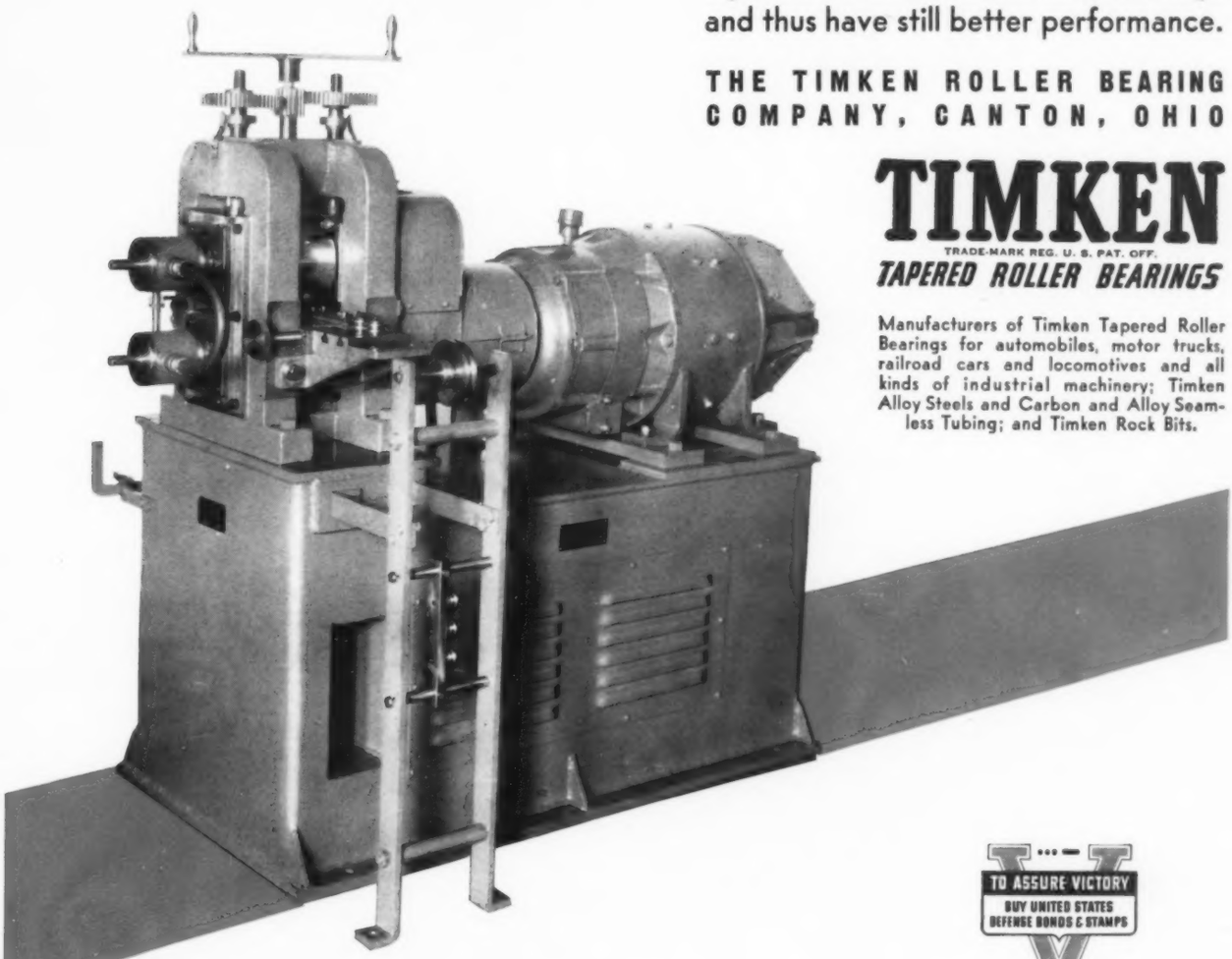
Timken Bearings are enabling machines of many types to keep ahead of war time demands. The same advantages will make them successful under the stress of post-victory conditions.

There is hardly any limit to the size of the thousands of Timken Bearing Equipped machines working for Victory. For example, contrast this comparatively tiny Waterbury-Farrel Wire Flattening Mill with one of the giant mills used to roll strip, sheets and plates.

Both operate on the same principle; both use Timken Roll Neck Bearings to assure utmost speed, precision and dependability; both consistently turn out highest quality products.

Most of the machines in service now will be equal to the severe tasks of the post-war period. Many will be redesigned to include more Timken Bearings and thus have still better performance.

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO



TIMKEN

TRADE-MARK REG. U. S. PAT. OFF.

TAPERED ROLLER BEARINGS

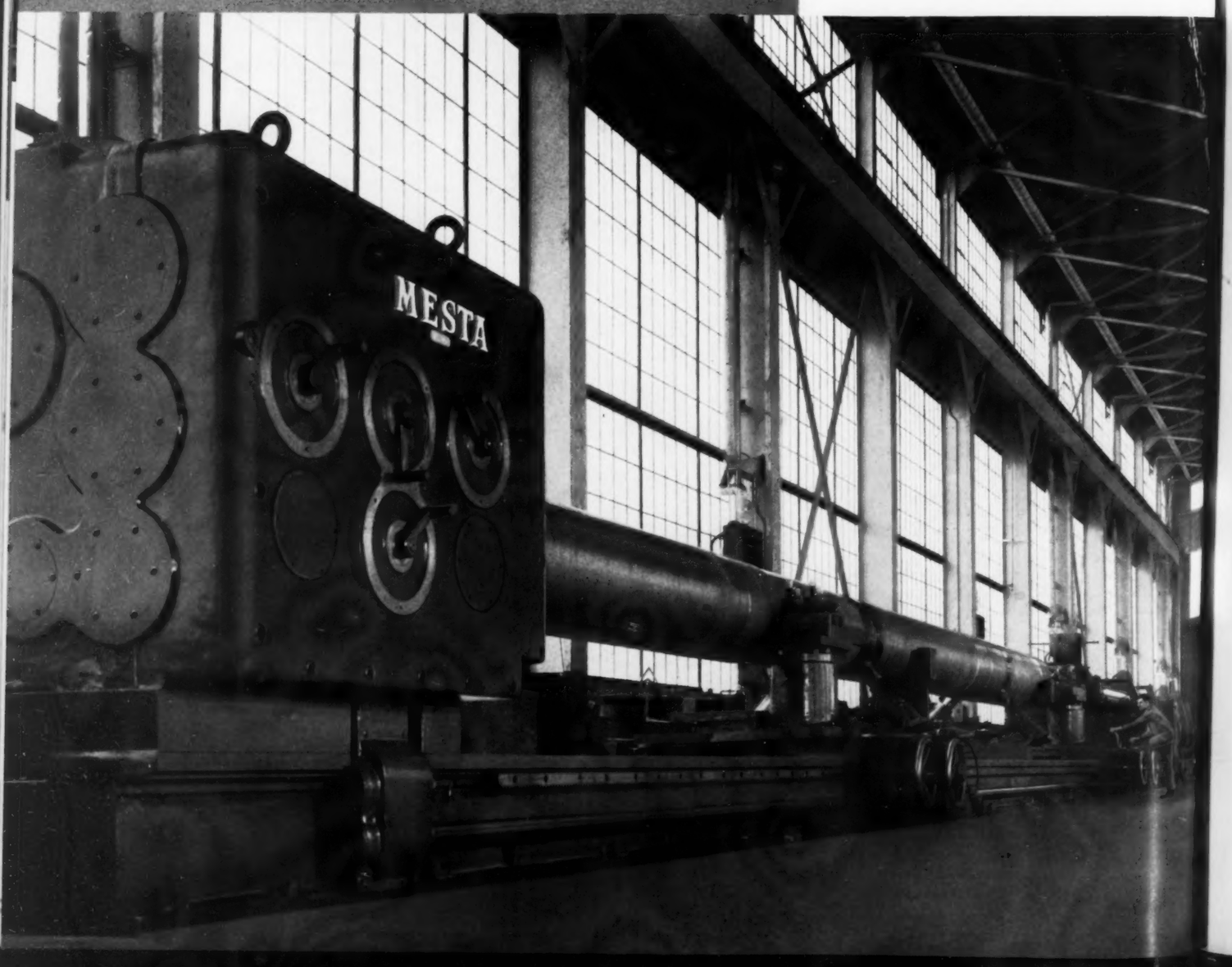
Manufacturers of Timken Tapered Roller Bearings for automobiles, motor trucks, railroad cars and locomotives and all kinds of industrial machinery; Timken Alloy Steels and Carbon and Alloy Seamless Tubing; and Timken Rock Bits.

MESTA

HEAVY DUTY TURNING AND BORING LATHES

MESTA MACHINE COMPANY, PITTSBURGH, PA.

MESTA was among the first to be awarded the FLAG of the UNITED STATES BUREAU OF ORDNANCE and NAVY "E" PENNANT.

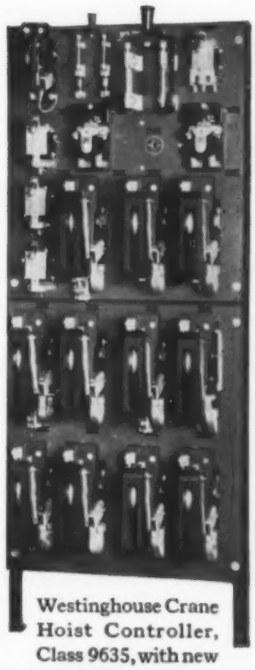


High-speed light-hook lowering speeds up crane operation

Westinghouse D-C crane control speeds up operation by giving *faster* light-hook lowering speed . . . *without* excessive speeds when lowering heavy loads . . . *without* complications and hazards of load relays.

Westinghouse crane control gives smoother braking action by means of graduated dynamic braking which accomplishes the greater part of deceleration before the magnetic brake sets. This reduces wear on brake lining and wheel and imposes less stress on the crane.

Inching control is made more precise—load handling is made easier, quicker, more accurate. Write today for bulletin DD-9600 containing full details. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., Dept. 7-N.

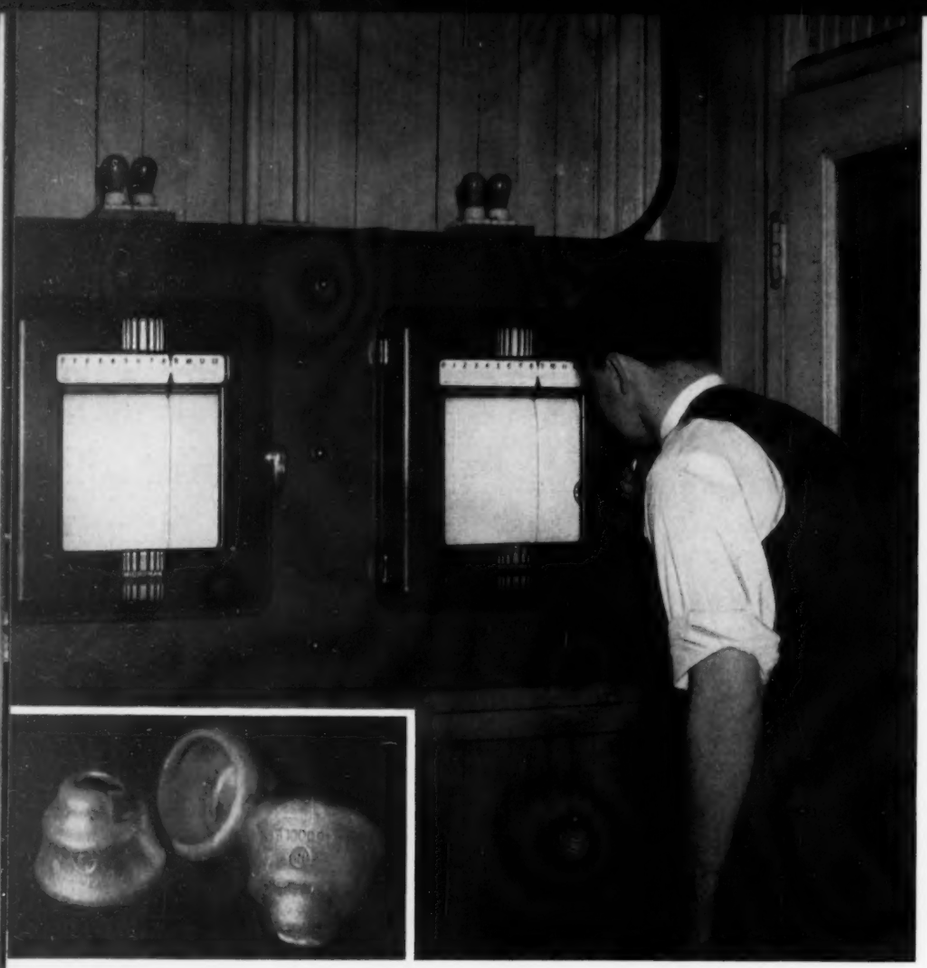


Westinghouse Crane Hoist Controller, Class 9635, with new 200 SM contactors.

J-21150

Westinghouse D. C. CRANE CONTROLLERS

W WESTINGHOUSE ELECTRIC



These two Micromax Pyrometers control temperature of Ohio Brass Co.'s galvanizing furnaces. Insert shows galvanized end caps for electric power-line insulators.

When An Ohio Brass Furnace Wants Heat Micromax Feeds It - - - Accurately!

Among metallurgical furnaces, the galvanizers are extremely uneven in their demands for heat, because the size or weight or number of parts to be handled is so subject to change.

And these furnaces don't always call for heat at the most convenient time, because their tons of molten zinc hold enough heat to postpone the call.

Furthermore, changes in outside temperature, wind direction, and other factors all help to make the heat-needs decidedly uneven.

To handle the complex control situations which result from the inter-action of the factors outlined above, Ohio Brass Co. has adopted Micromax Pyrometers. These sturdy control machines automatically consider all variables, setting and resetting themselves, continuously, if necessary, to hold temperature on the line. And they're not only versatile, but truly "micro-responsive." An observer can often see motion in the Controller's valve-moving machine, when he can't see any in the instrument itself. The result is control at its best—control which reduces rejects, minimizes re-processing, saves fuel, steps costs down and production up.

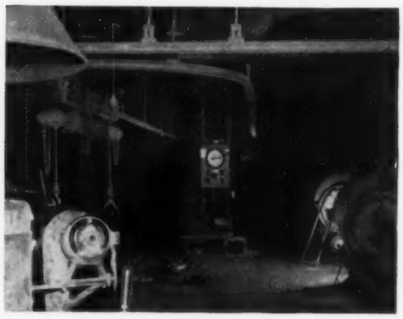
There's a Micromax model and range for any furnace; outline your problem and we will send the correct catalog.

Immersion Couple "At Home" With Micromax Pyrometer In Ohio Brass Foundry

Here's one of the foundryman's standard tools — the "Marshall-type" thermocouple — at work in the foundry where it was born. Mr. Marshall was an Ohio Brass Co. engineer when he developed this useful device, and here we see an O.B. Co. foundryman using a Marshall couple and round-chart Micromax Pyrometer, to tell whether the brass in the ladle is at correct pouring temperature.

This form of thermocouple is only one of many improvements in pyrometry in which we have been privileged to participate with our customers. For a quick overall picture of the kinds of instruments which are available, we'd suggest a look at our catalogs. Tell us about your temperature-measuring problem, and we'll send the appropriate book.

"Watchman's-Eye" View of Furnace Temperature



When his rounds bring the watchman to Ohio Brass Co.'s foundry, he stops at the point from which this picture was taken, picks up a thermocouple, and plunges it into the furnace partly shown in the left foreground. The couple is connected to the round-chart Micromax, and from where he stands the watchman can see the big black arrow wheel around the dial and point to furnace temperature. If it reaches the correct temperature, the watchman goes immediately on his way; if not, he first gives the fuel valve a turn. But he never has to trot back and forth between furnace and pyrometer, thanks to the "dial like a town clock" which enables him to read this Micromax from a distance.

Jrl Ad ENT-0600C(39)

LEEDS & NORTHRUP COMPANY, 4942 STENTON AVE., PHILA., PA.

LEEDS & NORTHRUP

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

BLAST FURNACE OPERATORS

Here's what you want in DRY BLAST

1. Delivery to blowing engines of cleaned air of constant temperature and moisture.

2. Ability to operate at any constant grain loading desired, from ONE GRAIN* upwards.

3. To have your dry blast plant operate at minimum cost with minimum maintenance expense.

BLAW-KNOX Can Furnish It

Blaw-Knox Absorption Type Plants, located pre-compression, give you these three vital points combined with other important engineering features. Write for information about Blaw-Knox Dry Blast Plants now operating and on order.

* For Pittsburgh atmospheric conditions, a blast furnace using 90,000 c.f.m. of dry blast will have less tons of moisture in the blast than if blown with atmospheric air by the following amounts:

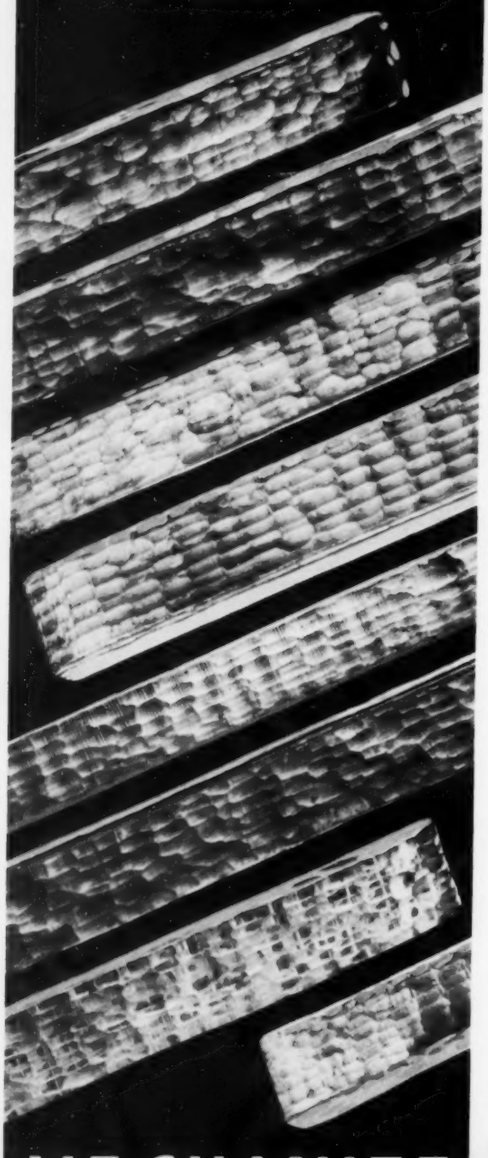
Air conditioned to 3 grains	*700 tons less*
Air conditioned to 2 grains	*4100 tons less*
Air conditioned to 1 grain	*7500 tons less*

BLAW-KNOX DIVISION *of Blaw-Knox Company*

PITTSBURGH, PA.

New York—Chicago—Philadelphia—Birmingham

KEEP THE BILLETS ROLLING



MAN-POWER ALONE NO LONGER WINS WARS

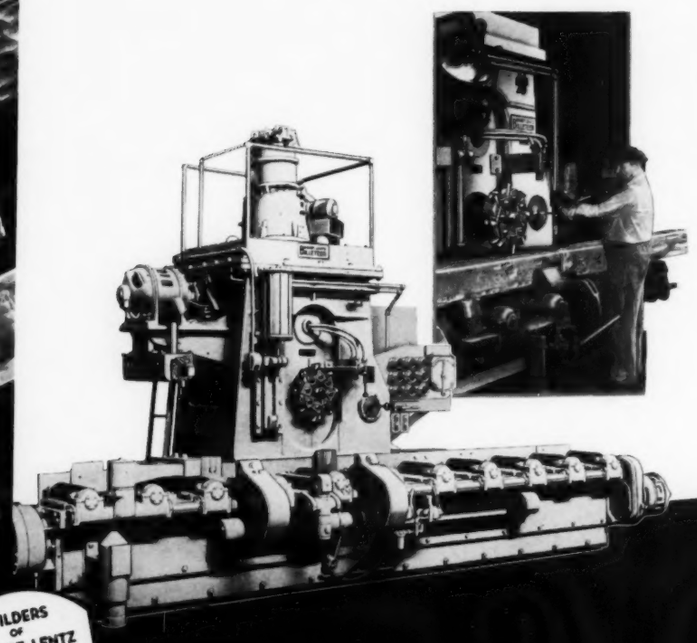
But the waste of it in war steel production can be a deciding factor.

Billet chipping by hand is still wasting too many man-hours. Releasing hundreds of hand chippers for more productive work is the contribution being made by Billeteers now in operation.

Industry-wide acceptance of this faster and more economical method of conditioning billets has helped remarkably in attaining record production.

BILLETEERS

are recognized as essential equipment and are being built on very high priority rating. Immediate action is advisable.

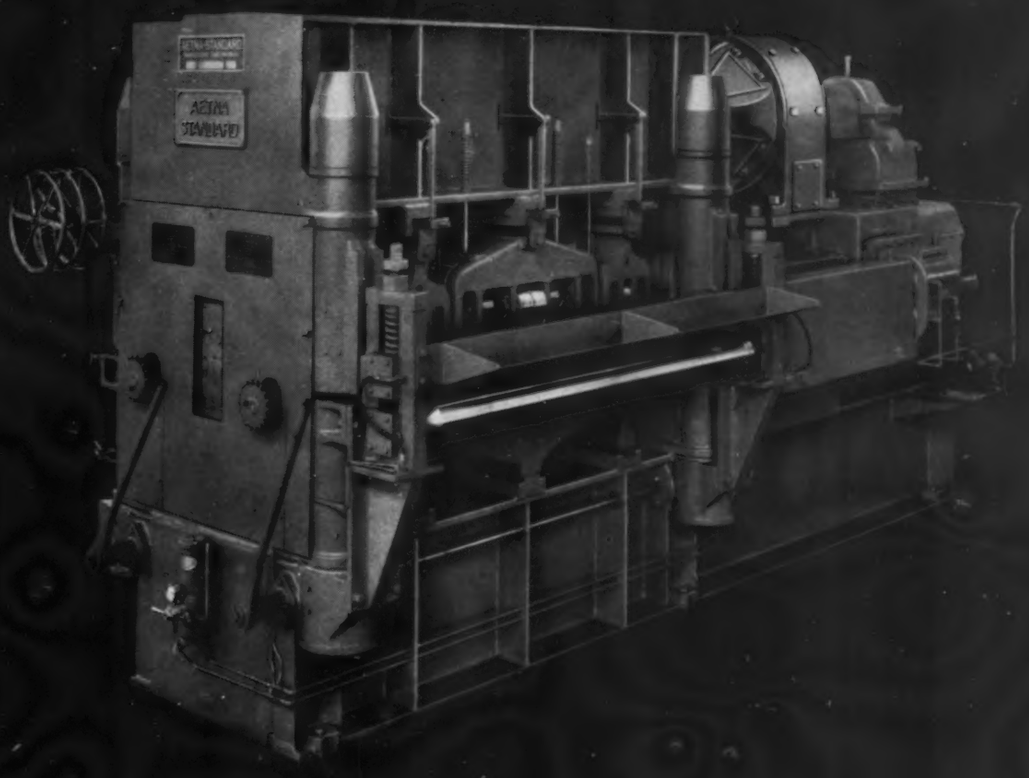


MECHANIZE TO WIN

BUILDERS OF BONNOT-LENTZ BILLETEERS ALSO CRUSHING PULVERIZING AND MIXING EQUIPMENT

THE Bonnot COMPANY
STEEL EQUIPMENT DIVISION
CANTON, OHIO

In America's Production for Victory

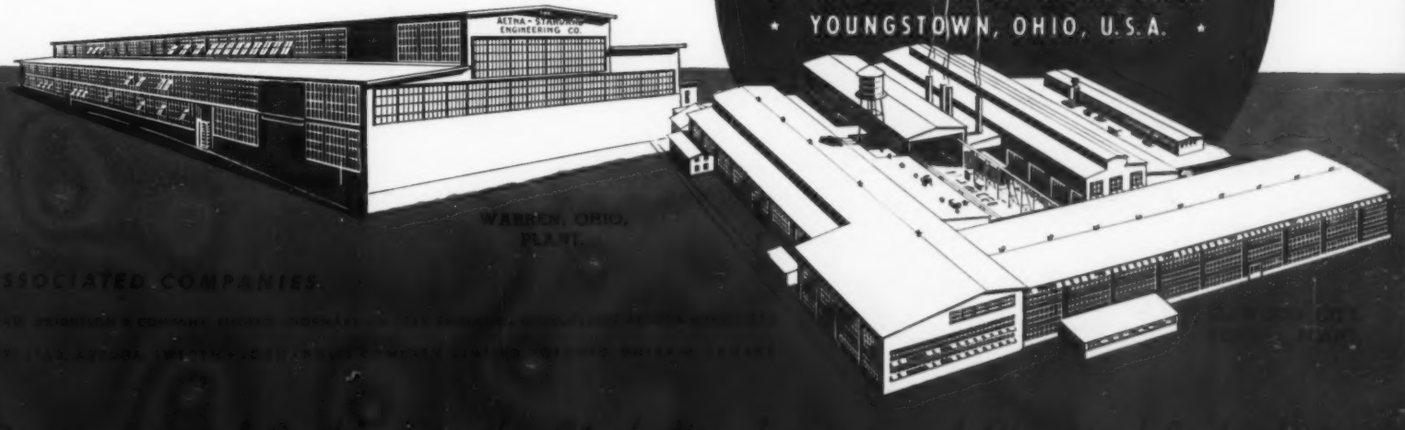


Where Does Aetna Fit Your Picture?

IF YOU ROLL ARMOR PLATE, Aetna's Heavy Duty Levellers are designed and built to level plate of various thicknesses. Speed and precision are two wartime requirements, this sturdy machine as well as other Aetna equipment will meet the most exacting demand.

The AETNA-STANDARD ENGINEERING COMPANY

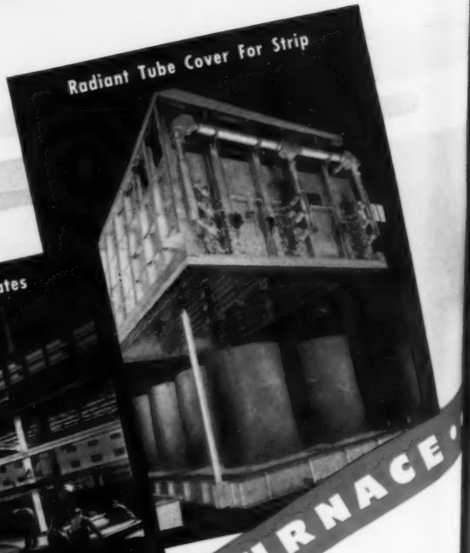
• YOUNGSTOWN, OHIO, U.S.A. •

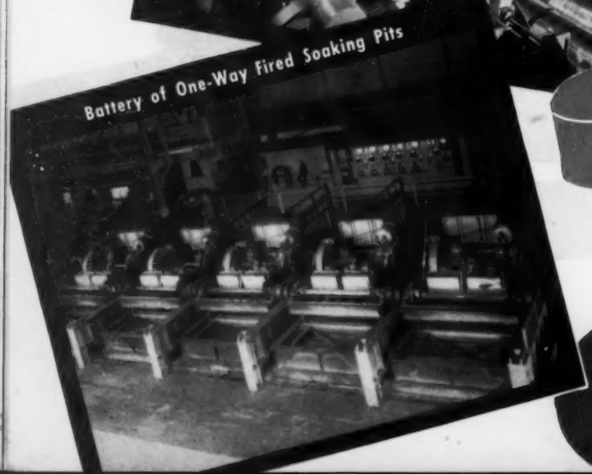


WARREN, OHIO, PLANT

* ASSOCIATED COMPANIES

"GIVE US STEEL!"





THERE'S AN SC FURNACE

● Beginning with the soaking pit there is an SC furnace for every steel mill operation. Shown on these pages are but a few installations of the more common types. To meet the demands of Defense Production Surface Combustion has, during the past year, designed and installed many special type furnaces.

SURFACE

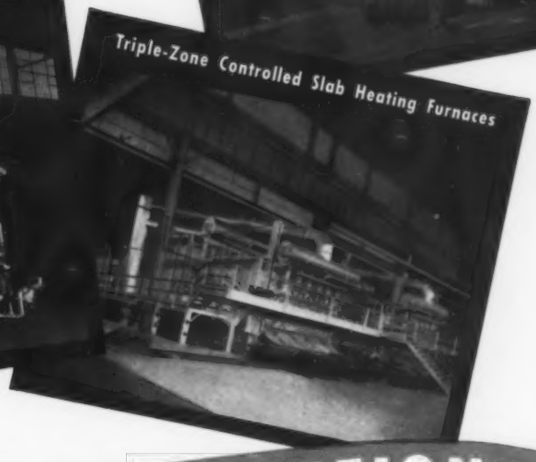
THE URGENT CRY OF DEFENSE

...and Surface Combustion Equipment is aiding the Nation's Steel Mills in meeting this Emergency Demand

Refractory Bed Burner Wire Patenting Furnace

Atmosphere Gas Generator For Clean Annealing

Annealing Spheroidizing Wire


Triple-Zone Controlled Slab Heating Furnaces

... FOR EVERY STEEL MILL OPERATION

● Tanks, planes, heavy artillery, anti-aircraft guns, shells, mechanized transports, jeep cars, swift torpedo boats and ponderous supply ships—these are the sinews of Defense. They call for steel... steel ...AND STILL MORE STEEL!

The steel industry is doing everything humanly possible to satisfy this urgent demand. It is estimated that during 1941 the industry produced close to 80,000,000 tons of steel, or 35 per cent more than the combined capacity of the Axis and Axis-dominated countries. This is 167 per cent more than produced in 1938 and 60 per cent more than produced in the World War record year of 1917.

Surface Combustion is proud of the part it has been privileged to play in helping the steel industry meet this all important demand. SC soaking pits, slab furnaces, normalizing furnaces, annealing and spheroidizing furnaces, armor plate and scores of other types of Surface Combustion furnaces are on the job helping to produce steel...day and night, in most of the leading steel mills.

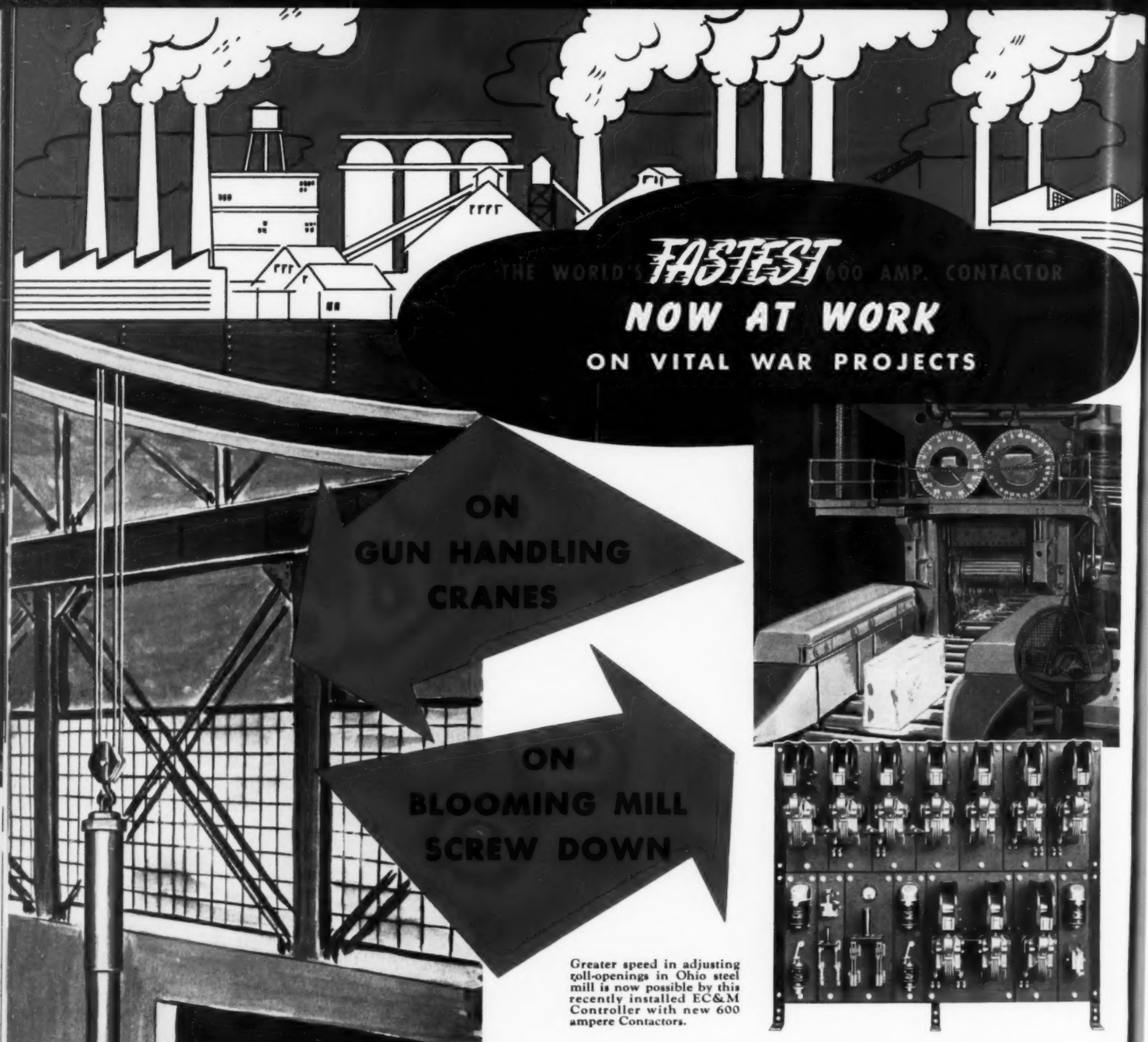
To take care of the unprecedented demand for SC steel treating furnaces, it has been necessary to expand our facilities and increase our personnel repeatedly... at present, our business is 98 per cent Defense. For the duration of the Emergency, Surface Combustion will continue to devote its all-out effort to the building of equipment for Defense . . . as rapidly as is humanly possible without sacrificing the high qualities which have come to be associated with Surface Combustion equipment.

SURFACE COMBUSTION CORPORATION · TOLEDO, OHIO

"SECURITY FOR AMERICA"

SC

COMBUSTION ★

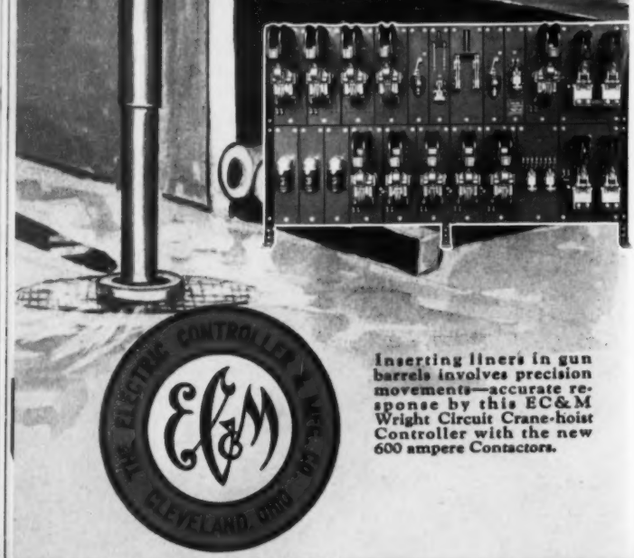


THE WORLD'S FASTEST 600 AMP. CONTACTOR NOW AT WORK ON VITAL WAR PROJECTS

ON GUN HANDLING CRANES

ON BLOOMING MILL SCREW DOWN

Greater speed in adjusting roll-openings in Ohio steel mill is now possible by this recently installed EC&M Controller with new 600 ampere Contactors.



Inserting liners in gun barrels involves precision movements—accurate response by this EC&M Wright Circuit Crane-hoist Controller with the new 600 ampere Contactors.

WHEN modernizing existing equipment or installing new units, many of America's plants—the arsenal of the democracies—are utilizing every opportunity to produce more in less time. Typical of this trend is the selection of EC&M D-c Magnetic Control with the World's Fastest new EC&M 600 ampere Contactor for these changeovers or new additions.

The quicker response of this new contactor permits an operator to get material or equipment into position faster and with fewer movements. This faster positioning helps increase production and accuracy. Furthermore, hitting the "bull's-eye" when adjusting rolls or setting crane loads reduces wear on motors and machines.

EC&M *LINE-ARC* Contactors are not only fast-operating but operate with low up-keep, too. Due to the *LINE-ARC* principle, contact-life has been greatly increased, resulting in less maintenance and greater continuity of service. For D-c crane and mill auxiliary motor drives, specify EC&M Bulletin 1145-B *LINE-ARC* Magnetic Contactor Control.

THE ELECTRIC CONTROLLER & MFG. CO. E&M CLEVELAND, OHIO

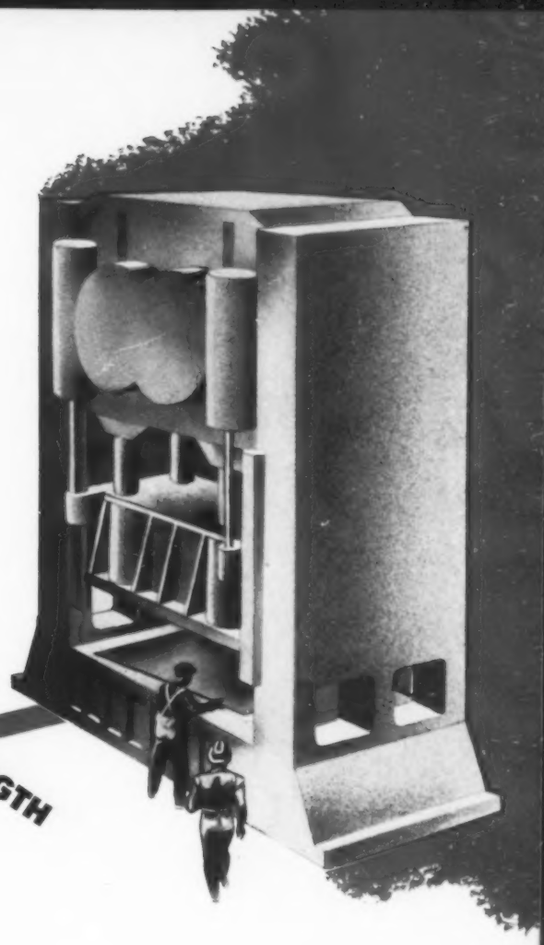
HEAVY DUTY MOTOR CONTROL FOR CRANES, MILL DRIVES AND MACHINERY • BRAKES • LIMIT STOPS • LIFTING MAGNETS AND AUTOMATIC WELD TIMERS.

When Modernizing -- Specify EC&M *LINE-ARC CONTACTOR*

"PHOENIXLOY"

CAST ALLOY IRON ROLL

FOR COLD REDUCTION AND TEMPER ROLLING



GREAT STRENGTH

GREAT STRENGTH AND DEPTH OF HARDNESS—RESISTS SPALLING

REMARKABLE RESISTANCE TO ABRASION DUE TO STICKERS

GREAT COMPRESSIVE STRENGTH

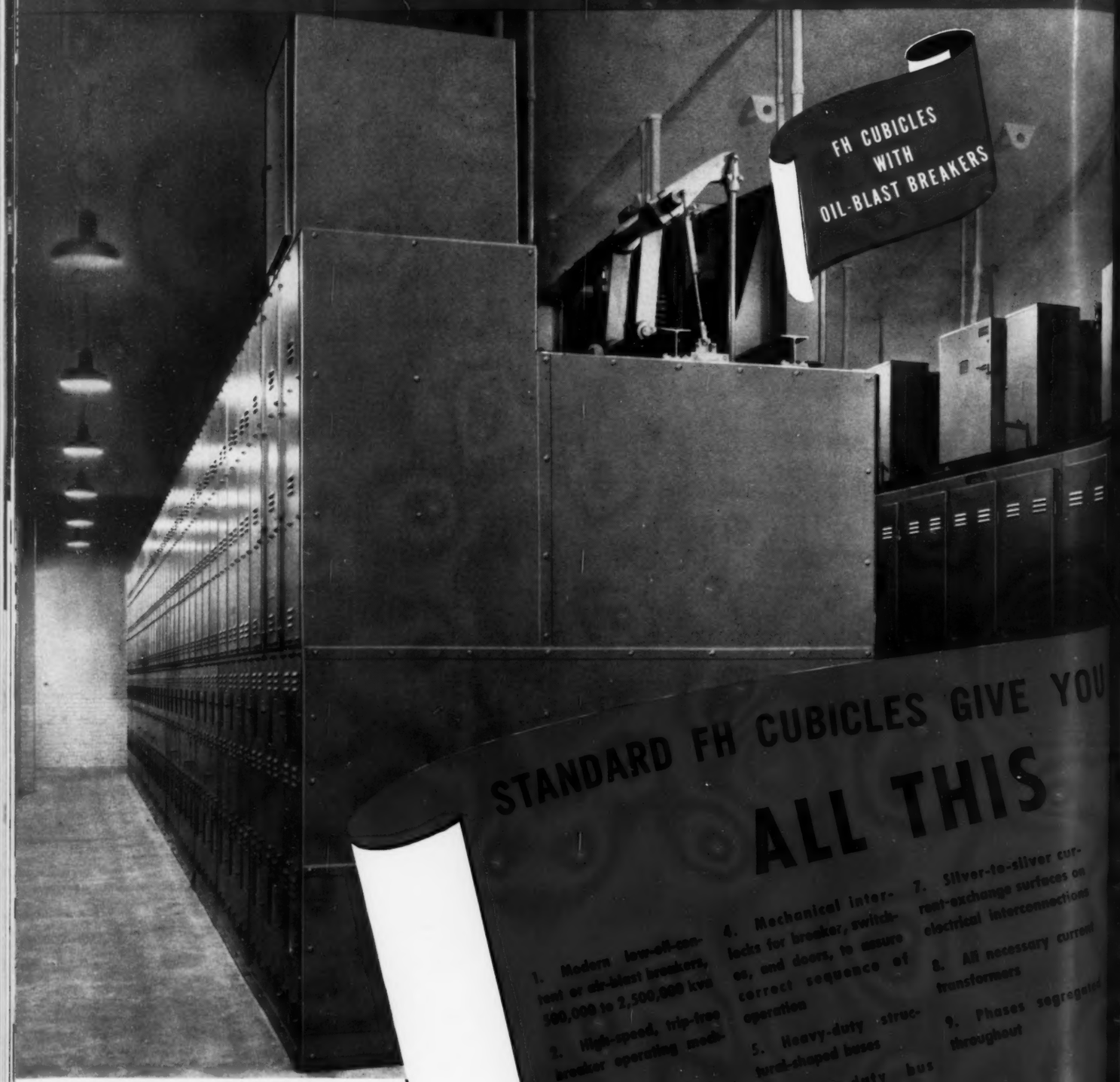
Pittsburgh Rolls are made for every rolling operation and every variety of mill.

3

Pittsburgh ROLLS

PITTSBURGH ROLLS DIVISION of BLAW-KNOX CO.—"Steel's Partner" • PITTSBURGH, PA.

Today It's ALL-IN-ONE Switchgear



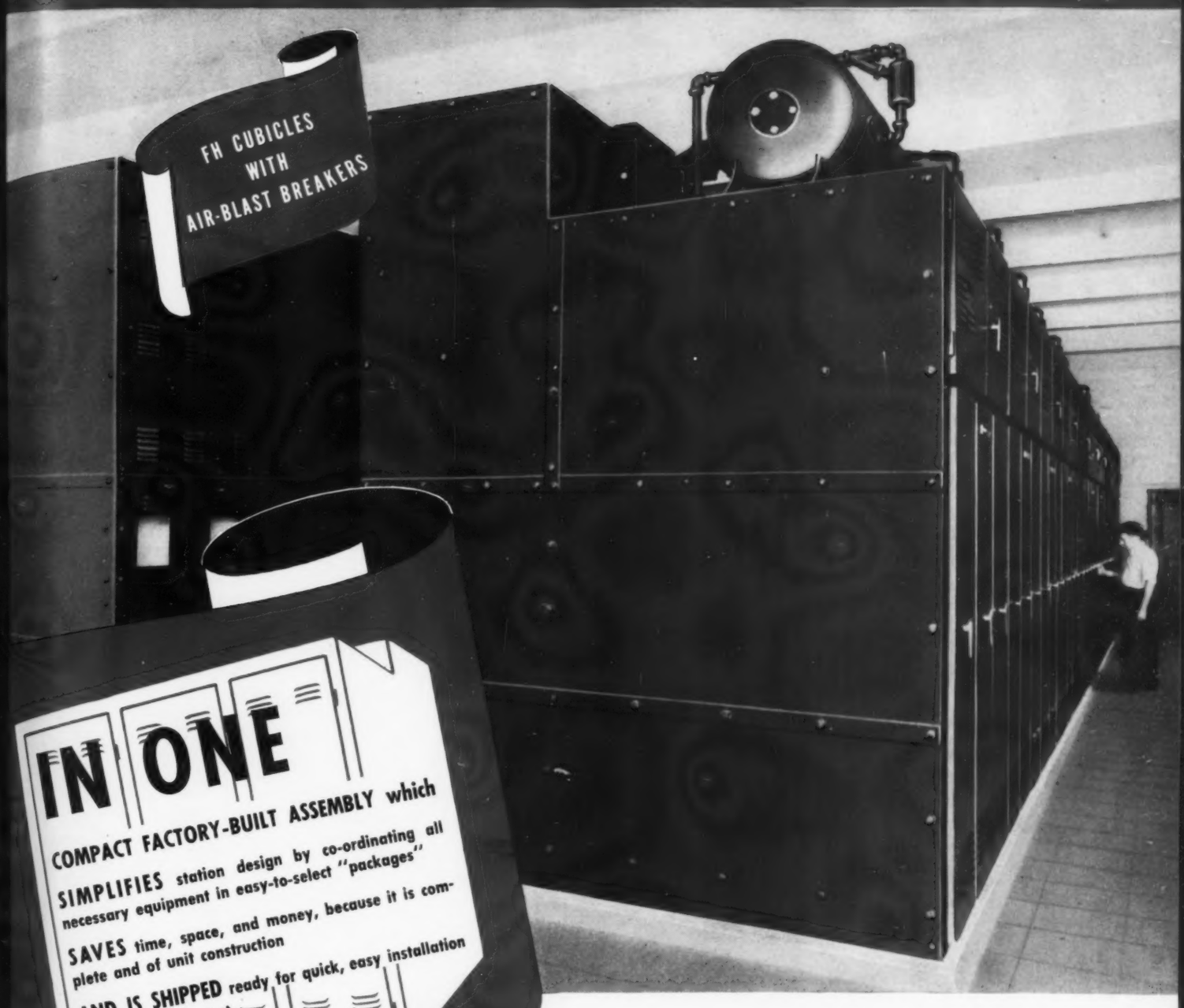
STANDARD FH CUBICLES GIVE YOU ALL THIS

1. Modern low-oil-content or air-blast breakers, 500,000 to 2,500,000 kva
2. High-speed, trip-free breaker operating mechanism
3. Six group-operated heavy-duty isolating disconnecting switches
4. Mechanical interlocks for breaker, switches, and doors, to assure correct sequence of operation
5. Heavy-duty structural-shaped buses
6. Heavy-duty bus supports
7. Silver-to-silver current-exchange surfaces on electrical interconnections
8. All necessary current transformers
9. Phases segregated throughout

General Electric and its employees are proud of the Navy award of Excellence made to its Erie Works for the manufacture of naval ordnance

Write for Bulletins GEA-3143 and GEA-3658, describing FH Cubicles with oil-blast and air-blast breakers respectively. General Electric Company, Schenectady, N. Y.

COMPLETE EASY TO SELECT EASY TO INSTALL



IN ONE

COMPACT FACTORY-BUILT ASSEMBLY which

SIMPLIFIES station design by co-ordinating all necessary equipment in easy-to-select "packages"

SAVES time, space, and money, because it is complete and of unit construction

AND IS SHIPPED ready for quick, easy installation at a predictable cost

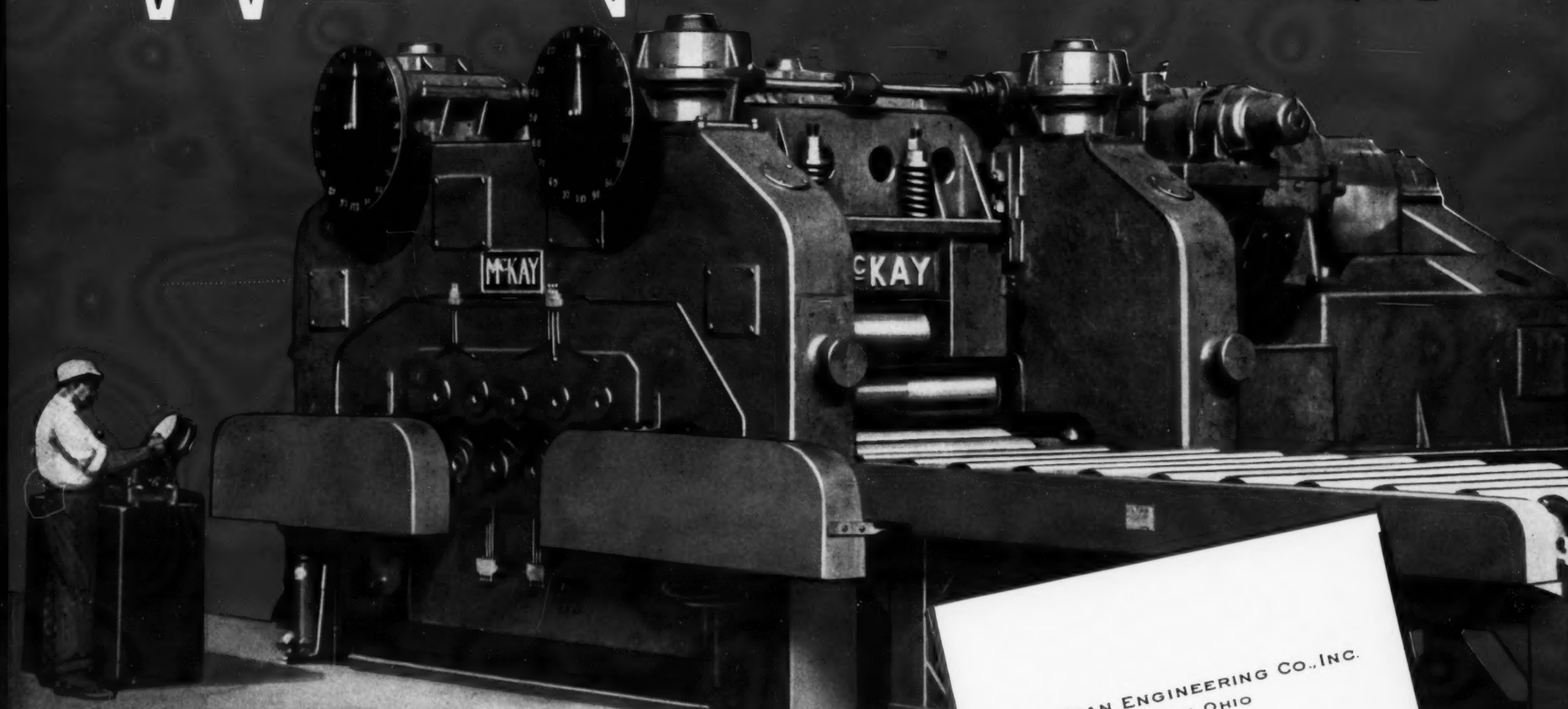
FOR POWER STATION SERVICE

UP TO 23,000 VOLTS AND 2,500,000 KVA

GENERAL ELECTRIC

WEAN

HEAVY DUTY ROLLER LEVELLERS FOR ARMOR AND SHIP PLATE



THE WEAN ENGINEERING CO., INC.
WARREN, OHIO

SPECIALISTS IN SHEET, STRIP AND TIN MILL EQUIPMENT

Associated Companies

LEE WILSON ENGINEERING CO. Cleveland, O.
THE McKAY MACHINE CO. . Youngstown, O.
FLINN & DREFFEIN CO. . . Chicago, Ill.
THE WEAN ENGINEERING CO. of Canada, Ltd., Hamilton, Ont.
THE WELLMAN SMITH OWEN ENG. CORP., Ltd. London, England

Subsidiary Company

THE BRODEN CONSTRUCTION CO. . . Cleveland, O.
Mfrs. of Strip and Wire Mill Machinery

"Hay!" We are not this slow!

Our expanded facilities and efficient organization offer you . . . . . .

Remarkably fast deliveries on North American Burners, Mixers, Regulators, Valves and Accessories.

If you are looking for dependable Combustion Equipment in a hurry, we invite you to try

Combustion Equipment by

NORTH AMERICAN

THE NORTH AMERICAN MANUFACTURING COMPANY

MANUFACTURERS OF INDUSTRIAL FUEL BURNING EQUIPMENT FOR GAS OR OIL

CLEVELAND, OHIO

BRANCH OFFICES WITH FACTORY TRAINED REPRESENTATIVES IN PRINCIPAL CITIES

FLOODLIGHTS

BUILT TO WITHSTAND SEVERE SERVICE

Pyle-National heavy duty floodlight equipment combines high efficiency optical design with the substantial construction that withstands the severest of mill operating conditions. Dependable protective lighting is assured, as well as efficient work lighting for yards, driveways, platforms, and other mill locations.

Pyle-National reflector design and light control lenses mean high efficiency lighting properly distributed for maximum usefulness. Ability to select from a wide range of types and sizes means that individual lighting requirements can be easily and economically met.

Substantial weatherproof construction with sealed interior afford maximum protection to reflector and lamp bulbs. The need for interior cleaning and other maintenance is greatly reduced. Adjustment locks are provided, insuring return of projectors to original position after re-lamping.

Pyle-National floodlight equipment is available in a complete line of standard types from 100 watt to 5000 watt size, including portable types, to meet the varied needs of mill lighting.

Catalog No. 2100 gives full information on all types, with beam efficiency, candlepower, and light distribution data. Copies will be sent upon request.

THE PYLE-NATIONAL COMPANY
1334-58 North Kostner Avenue • Chicago, Illinois

Offices: New York • Baltimore • Pittsburgh • St. Louis
St. Paul • San Francisco

PYLE-NATIONAL
ELECTRICAL EQUIPMENT
• SINCE 1897 •

CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS

Kodachrome of Pouring at Hubbard Division

MEN, MORE THAN MACHINES

Men, more than machines are responsible for Continental's continued leadership and pioneering achievements in rolls, castings and heavy equipment.

Men whose experience, skill and craftsmanship have pioneered and perfected equipment for the steel industry are contributing their share for National Defense. Their contribution is production of castings, rolls for strip, bar, billet, blooming and merchant mills and of vital parts and machinery for Defense on land, sea and in the air.

Men of Continental are proud of the part they are playing. They are contributing their energy, skill and experience to develop new strength for our American Defense with Steel.

While National Defense has first call on Continental, our engineers are eager to cooperate with you on any problem concerning steel mill equipment.

Continental operates four plants, strategically located at East Chicago, Indiana, Coraopolis, Pennsylvania and Wheeling, West Virginia.

CONTINENTAL ROLL & STEEL FOUNDRY COMPANY

CHICAGO PITTSBURGH

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This is the rule at SKF; and—despite production pressure—the peacetime reputation of SKF bearings is being amply sustained under the sterner demands of war.

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BALL BEARINGS **SKF** ROLLER BEARINGS

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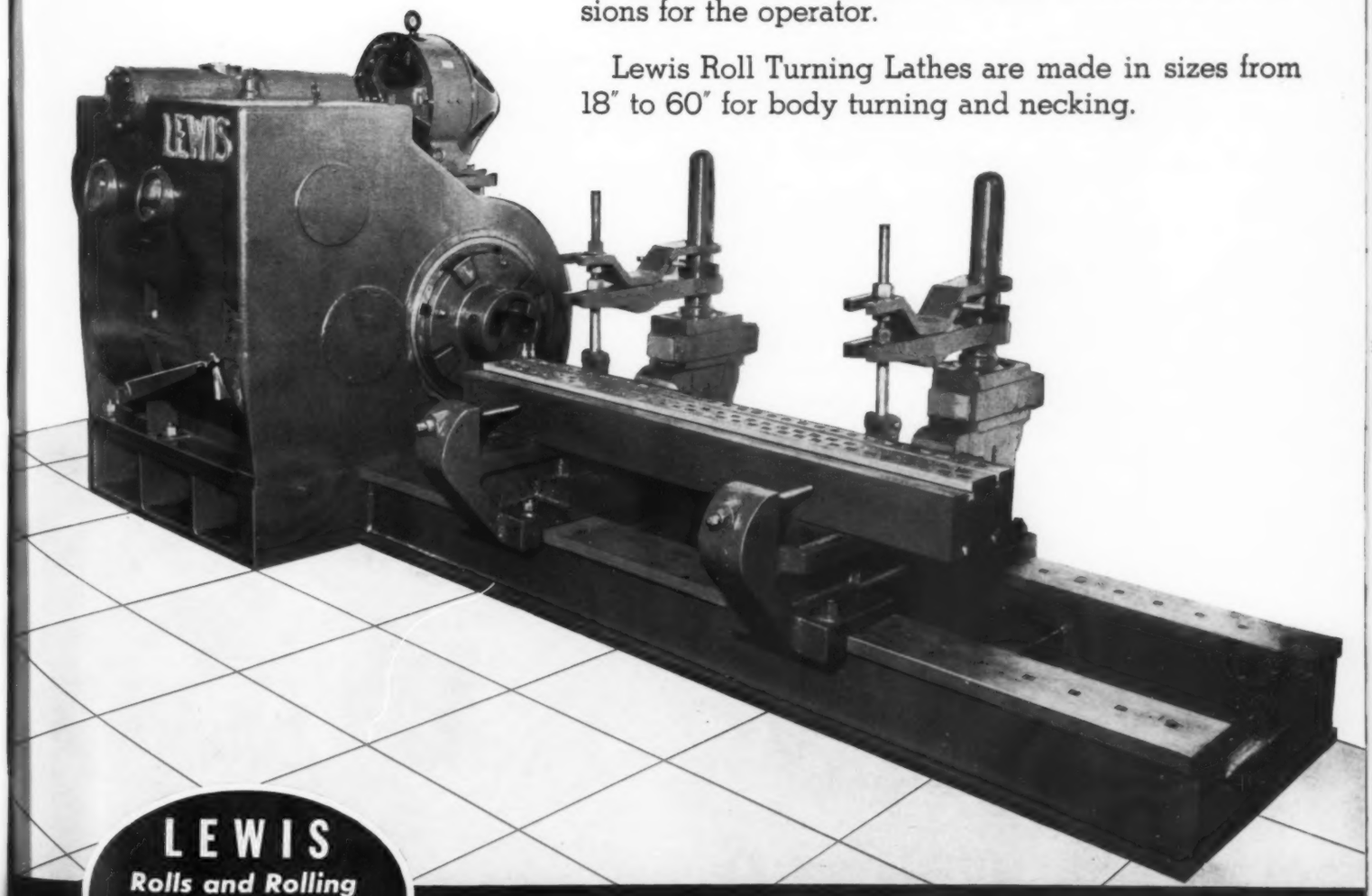
ROLL TURNING LATHES

NOT A SINGLE REPAIR PARTS ORDER IN 10 YEARS

The best proof of the sturdy and simple construction of Lewis Roll Turning Lathes is the fact that service records show no sales of replacement parts for the last ten years. These lathes are roller and ball bearing equipped with combination gear reduction for noiseless operation.

Specifications include totally enclosed headstock—worm and worm wheel drive—pressure lubrication—extreme accessability of all parts—and safety provisions for the operator.

Lewis Roll Turning Lathes are made in sizes from 18" to 60" for body turning and necking.



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Rolls and Rolling Mill Machinery step up tonnage

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DIVISION OF BLAW-KNOX CO.
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THE "CORRECT" ANSWER TO AN IMPORTANT PROBLEM IN VITAL DEFENSE PRODUCTION

Problem: The open gears at the right must be protected by a lubricant against wear due to: (1) Heavy or shock loads, (2) Dust and dirt in the air, (3) Presence of water.

The *correct* lubricant for this job must provide: (1) A tough film to prevent metal-to-metal contact, (2) A thin film to prevent accumulation of abrasives and packing of clearances, (3) A tough "waterproof" coating.

Answer: We have created a unique lubricant for this job — *Gargoyle Viscolite Fluid.* It can be applied by hand without heating, or be fed by mechanical devices. It is made with a quick-drying, non-inflammable diluent. As the diluent evaporates, a tough, black, thin skin is formed. *This film won't squeeze out or throw off!* As the film is thin, there is no opportunity to hold or pack dirt and dust. The tough coating sheds water like a duck. In many cases, Gargoyle Viscolite Fluid has helped reduce consumption more than 50%. This lubricant is available in four viscosities to fit every set of operating conditions.

TO HELP MAINTAIN CAPACITY PRODUCTION, CALL IN

SOCONY-VACUUM for "Correct Lubrication"

GARGOYLE Lubricants

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GARGOYLE VISCOLITE FLUID IS APPLIED IN LIQUID FORM. NO PRE-HEATING IS NECESSARY.
THIS UNIQUE LUBRICANT DRIES QUICKLY – LEAVING A TOUGH, BLACK SKIN TO CUSHION SHOCK LOADS.

WESTINGHOUSE IS READY TO HELP PRODUCE

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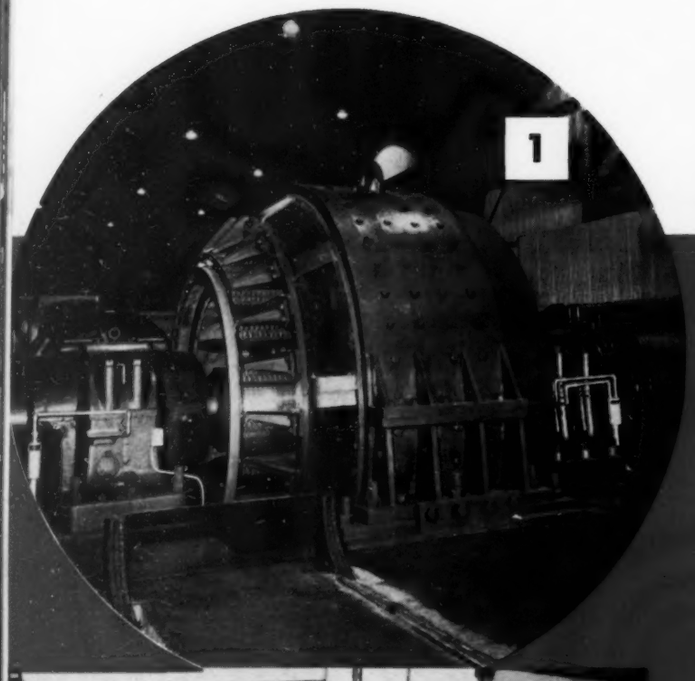
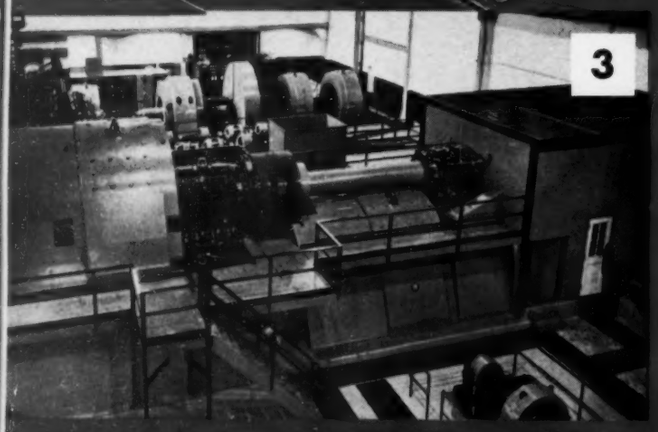
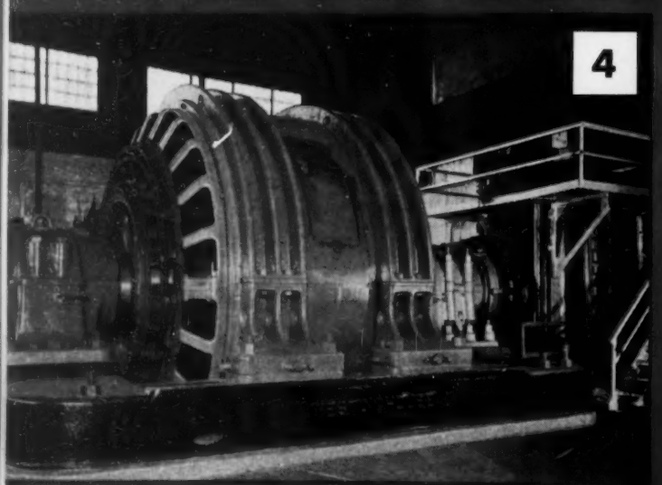
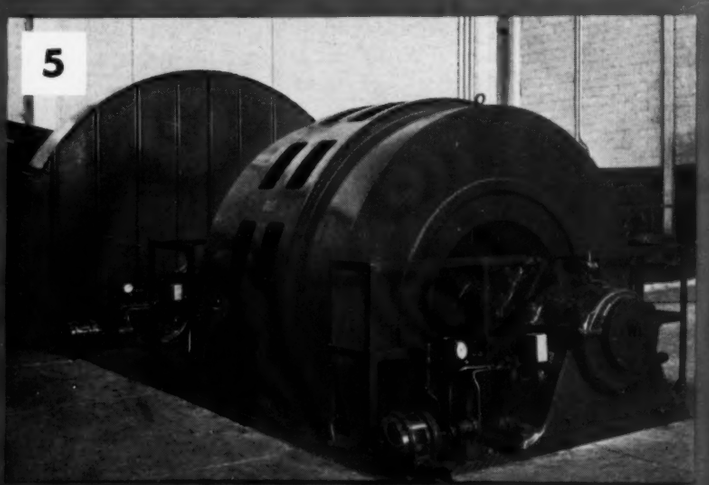




1. 7,000 hp Blooming Mill motor drive.
2. Twin motor drive totaling 10,000 hp driving the horizontal rolls of a Universal Slabbing Mill in the Pittsburgh District.
3. These two 5,000 hp motors form a twin drive for a Universal Slabbing Mill.
4. 8,000 hp 50/120 rpm motor driving a 46" Blooming Mill.
5. 4,500 hp slip ring induction motor driving the Spreading Stand of a Universal Plate Mill.





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Steel

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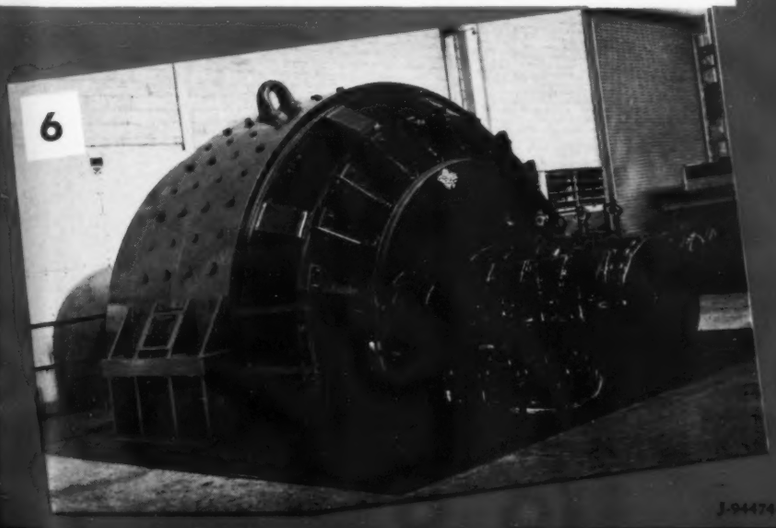
6. This 7,000 hp motor drives the Reversing Roughing Stand of a Universal Plate Mill.
7. 4,000 hp reversing plate mill drive in a Southern Steel Mill.
8. The main and edger drives for a Slabbing Mill in the Middle West. These three motors have a total horsepower of 12,500.
9. This 7,000 hp motor drives a 46" Blooming Mill in the South.
10. 10,000 hp twin double armature drive on a Blooming Mill in the Chicago District.



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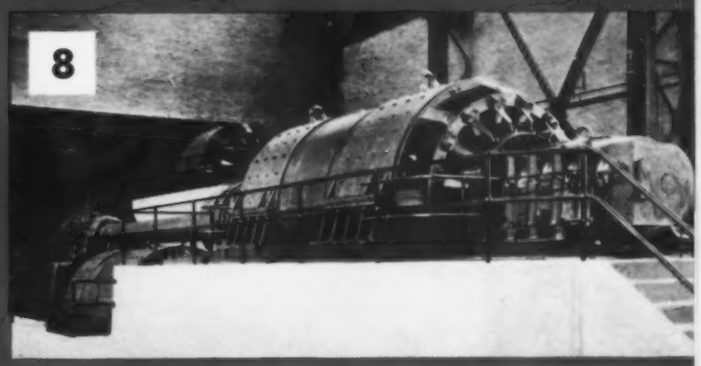

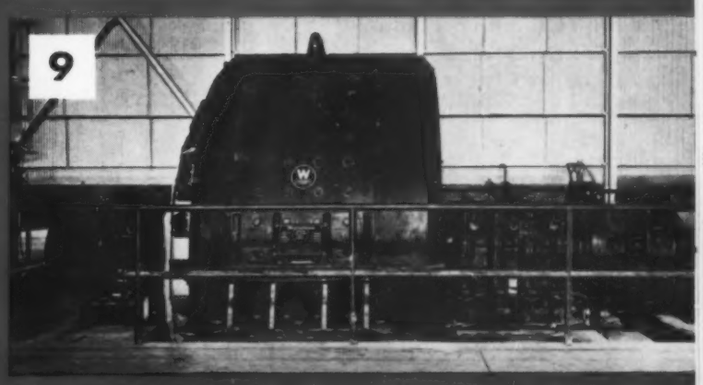

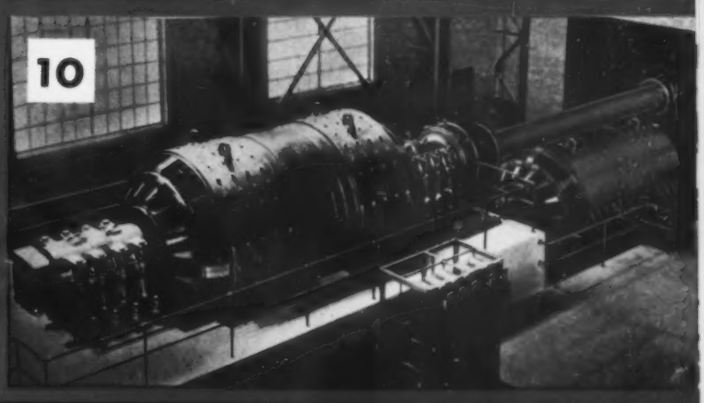

ELECTRICAL PARTNER OF THE STEEL INDUSTRY

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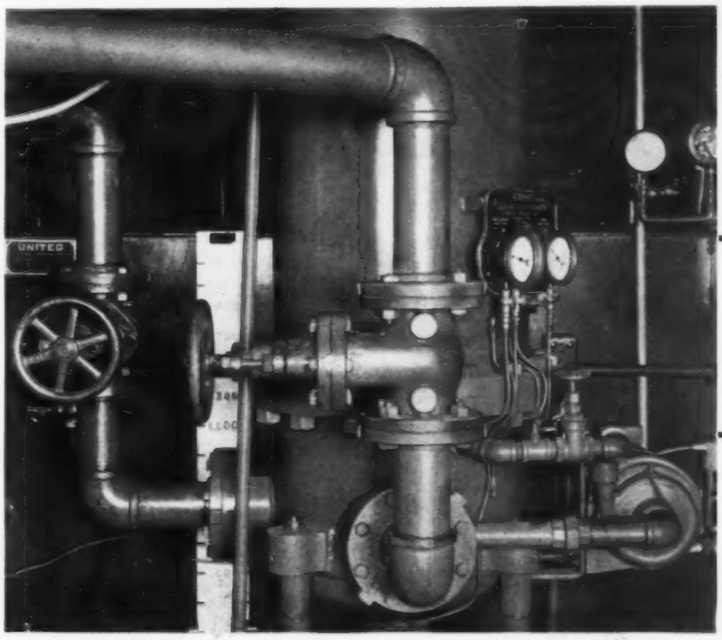
HOT AND COLD STRIP MILLS
that never need wait for Fluid-Cleaning

Lubricating systems, recirculating spray systems, roll body coolant systems, in the majority of continuous hot and cold strip mills, have Cuno continuous protection.

Cuno Filters positively remove all solids larger than specified — protecting bearings, spray nozzles and other parts from damage or clogging.

A special Cuno feature is the method of cleaning the filter element without interrupting the flow of liquid. Imbedded solids are removed as well as those adhering to the surface of the element, and the filter is made self-cleaning by means of a motor drive. There is no need to remove the element for either cleaning or frequent replacement.



1 LUBRICATING SYSTEM (*above*)

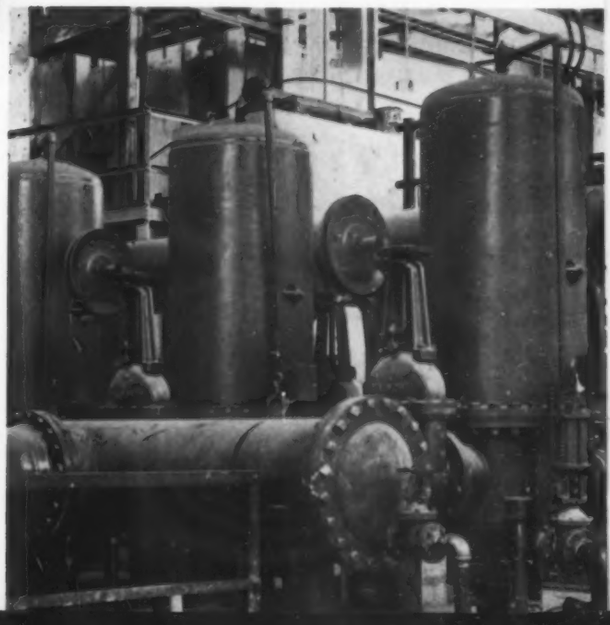
Cuno Auto-Klean Filter on 80″ hot strip mill, protecting gear reduction system — 435 g. p. m. of lube oil. Pinion stands, oil bearings and motor bearings on this mill are also Cuno-protected.

2 ROLL BODY COOLANT (*left*)

Cuno Flo-Klean on cold strip mill. Backwash is returned to the system — there is no loss of soluble oil or other valuable liquids.

3 DESCALING SPRAY SYSTEM (*below*)

Cuno Flo-Klean on 54″ hot strip mill, protecting spray nozzles from abrasive particles in spray water, permitting recirculation. 10,560 g. p. m.



A new bulletin, "Quick Facts," describes the Cuno Auto-Klean, recommended for lube systems, and the Cuno Flo-Klean (backwash type), especially designed to handle descaling spray and coolant systems.

KEEP FLOW ON "GO" WITH

CUNO

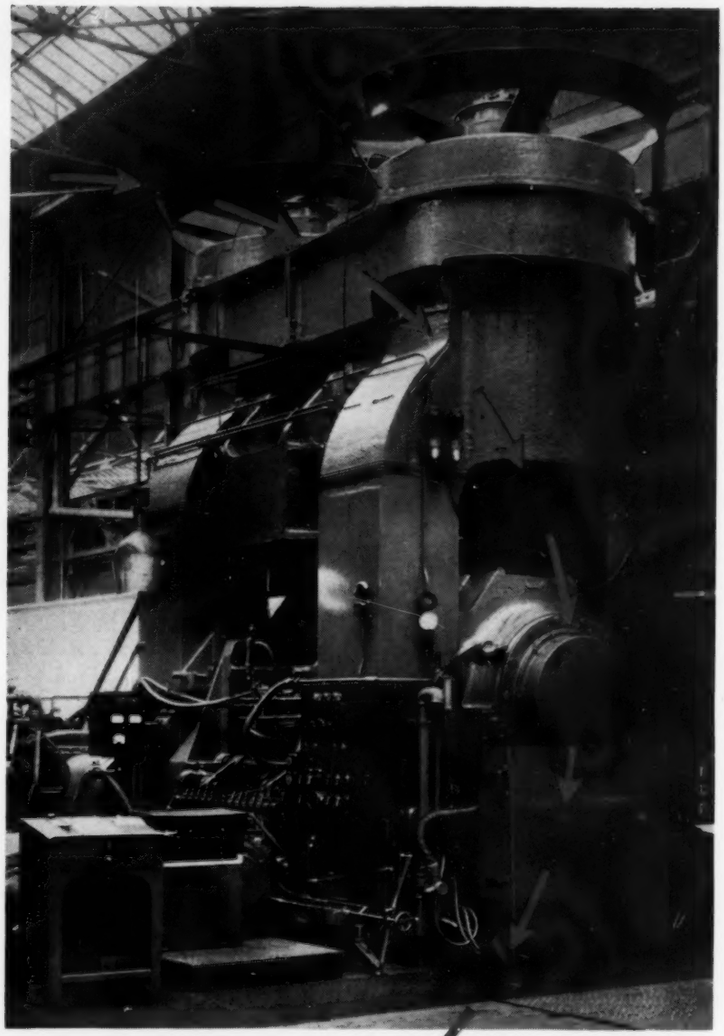
THE "FILTER-FINE" STRAINER

CUNO ENGINEERING CORPORATION

902 South Vine Street, Meriden, Connecticut

ACCURACY BEGINS IN THE BEARINGS

We may be able to help you—NOW



Mills equipped with Morgoil Bearings are rolling (1) foil *one-quarter of a thousandth of an inch in thickness* at speeds up to 600 ft. per minute; (2) hot strip steel *94" wide* at speeds in excess of 2000 ft. per minute; (3) No. 5 wire rods *to a ± .005 in.* diameter at speeds of over 4000 ft. per minute . . .

These performances are made possible by the absence of metal to metal contact and complete freedom from wear in the bearings. Morgoil Bearing design is based upon the well-known action of an oil film under pressure between two highly finished surfaces. Load-carrying ability of Morgoil Bearings at all speeds is proved under severe service conditions: for instance—the world's largest and most powerful 4-high reversing cold mill, shown here.

Morgoil Bearings have been installed in many existing mills, replacing bearings of other types. If you are interested, we shall be glad to see what we can do for you—*immediately.*

MORGAN CONSTRUCTION COMPANY
Worcester, Massachusetts

MORGAN
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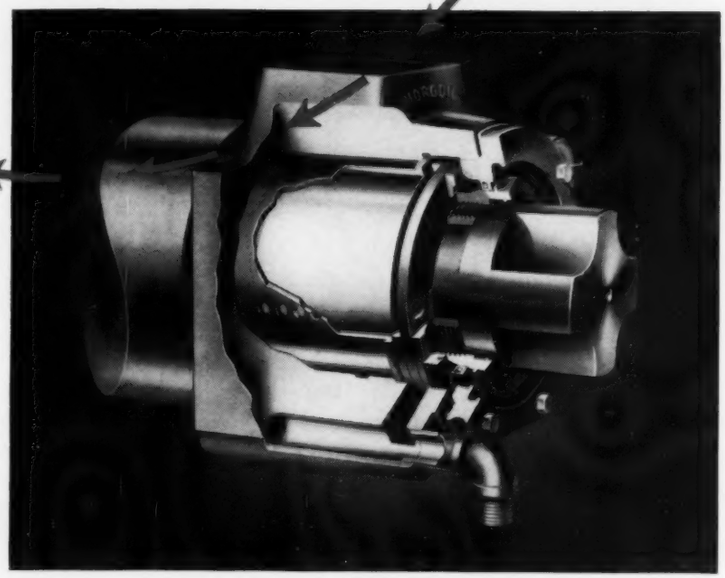

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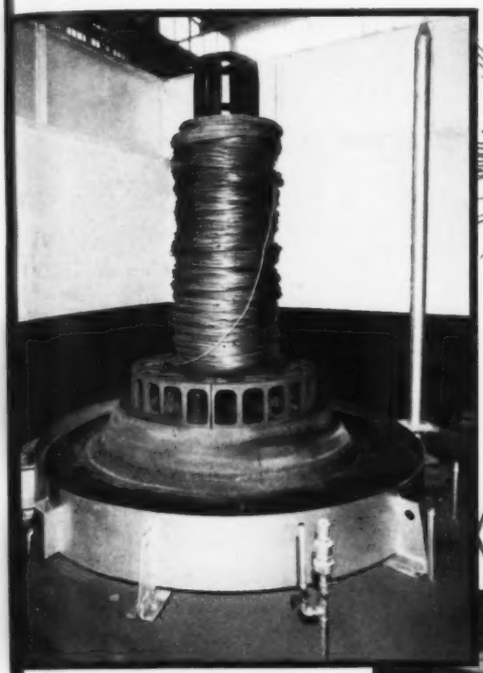
MORGOIL BEARINGS

WILSON

Cylindrical Bell Type Furnaces for

BULLET CORE

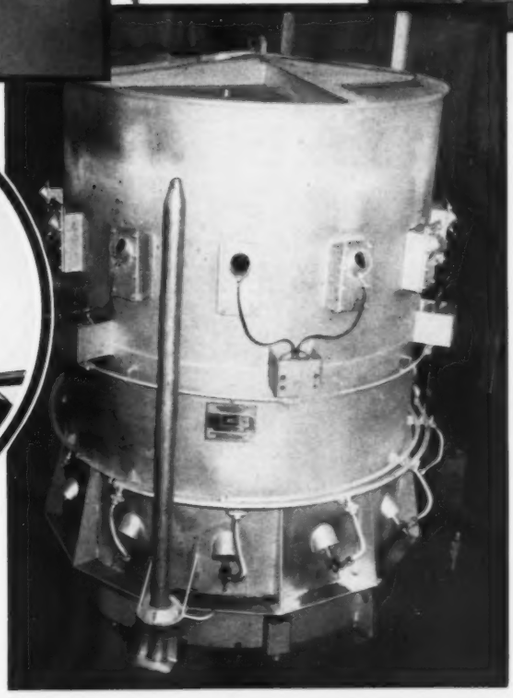
ROD & ALLOY COIL ANNEALING



Standard Wilson Bell Type Unit for Bullet Core Material

Another Wilson Rod Coil Annealing Installation

Note Alloy Base Covering and Recirculating Fan

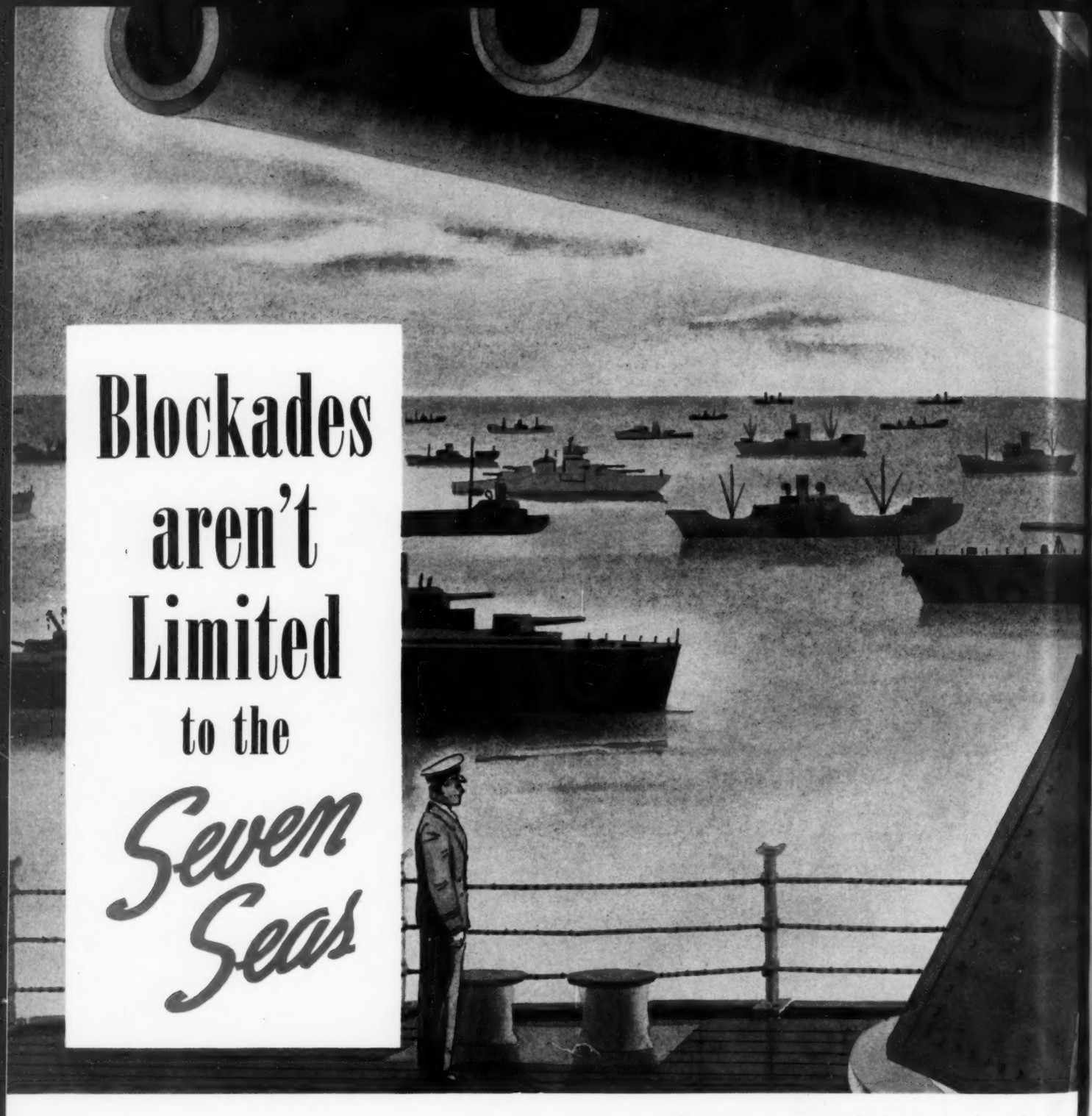


For high quality annealing of alloy and tool steel coils, particularly for bullet core material, the standard Wilson cylindrical bell type furnace for single stack charges is the fastest, most accurate and most flexible unit available.

An Exclusive Development of

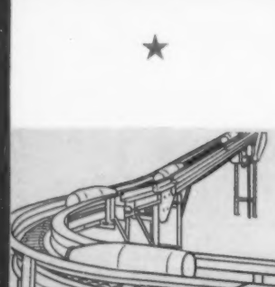
LEE WILSON ENGINEERING CO.

1200 Baugh Street • Cleveland, Ohio



Blockades aren't Limited to the *Seven Seas*

★ ★ ★ ★



If you are manufacturing war material, or anything vital to the success of the war effort, you can get Mathews Conveyers to handle that material. Rely as usual on your Mathews Engineer.

ATHEWS CONVEYERS FOR MECHANIZED PRODUCTION

Mathews CONVEYER CO.

ELLWOOD CITY, PA.

•The most serious blockades in America's war effort today are those occurring in the great plants producing war materials. Delay in getting parts and assemblies from one machine to the next, and the lack of a definite production pace tieing together all departments, is keeping production down. Mathews engineering hours are devoted entirely to the solution of these problems. Mathews Conveyers are breaking these blockades by speeding materials from one machine to the next, through inspection and into cars or ships. The success of our production depends upon our keeping materials moving. Matthews Conveyers are moving them.

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PLASTIC BINDING U. S. PATENT NO. 1870285 LICENSE NO. 50

SLITTING--
An Old Problem
MODERNIZED

By George Kentis

Sales Engineer

THE YODER COMPANY

Cleveland, Ohio

Presented before the A. I. S. E.
CLEVELAND DISTRICT SECTION

▲ WHEN a steel mill or warehouse requests the visit of an engineer to discuss slitting, it is usually in an effort to increase production and decrease the cost of slit-to-order strip or sheet steel. This is not a new problem, as will be noted from history, which tells us that the nail industry was of considerable importance in Sweden during the year 1590 and a decrease in manufacturing costs would make Sweden the world market supply house for this produce. In answer to Sweden's problem, Godfrey Bochs, an ingenious iron worker, introduced the slitter and Sweden almost monopolized the nail market through its use. Shortly after, in the early 1600's, England was suffering great losses in nail exports, and the nail industry had a very unique plan. A man by the name of Foley—a fiddler, living near Strourbridge, England—visited Sweden and fiddled his way into the iron works, succeeded in seeing the machine and observing its operation. Returning to England, he and his associates built what they thought was a duplicate unit, but it would not work, so Foley returned to Sweden and again fiddled his way into the iron works and a job as resident watchman, which gave him time to make sketches of the Swedish machine. Upon his return to England, the machine was put into operation and a description of it indicates that it had two spindles on which were mounted a series of steel faced discs, working against each other, dividing a 6 in. wide plate of iron into a number of rods from which nails were made. The drive was through a turnstile rotated by hand. The material, after slitting, was called bundle iron, which term may still be heard in some rod mills.

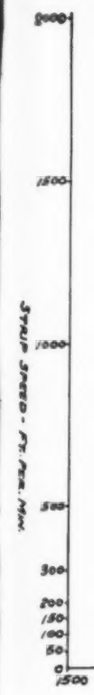
There are traces of English, Bohemian and Roumanian slitters being used in the United States as early as the late 1700's; however, very little is known of their design or operation. In the early 1800's, American manufacturers had produced slitters for ferrous and non-ferrous metals, but these were built along the pattern of the crude European machines and were only a slight improvement in design and operation. In the middle 1800's, the American manufacturers of slitters were making a desperate effort to keep abreast of the steel industry which had developed the rolling mill to a point where maximum speeds of 350 feet per minute were not unusual. This pertained to narrow sheet and narrow strip mills with capacity to produce up to 6 in. wide by approximately $\frac{1}{8}$ in. thick strip up to this speed. Looping mills and Belgian mills were being used to produce some narrow short length strip stock and the continuous mill was in its infancy.

With these production speeds in mind, the slitter manufacturers improved the sheet slitter to work at 75 to 100 feet per minute and developed other units with it for the purpose of slitting short length coil strip and although crude, they answered the purpose. Some mills and consumers were beginning to see the advantage of coiled strip stock over short length sheets so that by about 1875, the coil slitter had a place in the mills, but speeds of 75 to 100 feet per minute were still used.

The non-ferrous industry was ahead in slitter speeds in these early years of development due to the ease of working the softer metals and the length of coils which could be made, and also the non-ferrous metals, particularly zinc, were in great demand in the container industry. Terne plate equipment was also in use, but on sheet length material. These units generally were of such a design that they could not be easily converted to coil slitting. Tin-plate, because of its numerous process handlings, was made in convenient size sheet form and small slitters for this purpose were numerous, although they also were geared for approximately 100 feet per minute.

General catalogs and pamphlets showing coil strip slitting equipment were in circulation about 1880 and showed slip clutch recoilers with oil soaked wood pegs, leather or rope acting on iron as friction surfaces. This type of equipment was generally furnished up to the early 1920's when the binding of asbestos into suitable cloth, which could be used as clutch lining, was found to give good service at higher speeds with comparable maintenance cost. Band and shoe clutches became numerous although it must be remembered that strip widths were not much over 18 in. and gauges were fairly light, making it unnecessary to use more than 10 to 15 hp at speeds of 100 to 150 feet per minute.

Plotting the change in slitting speed from the 1600's to 1931 and comparing them with a curve of rolling mill speeds over a like period of years, there is only a slight similarity. Although the slitter of today does not compare in speed with the modern rolling mill, consideration should be given to the difficulties encountered



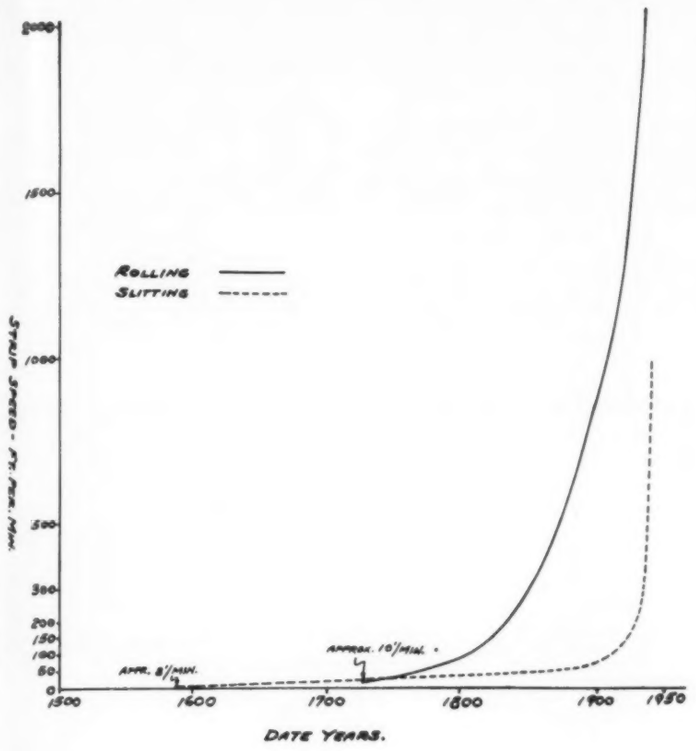


Chart showing speeds of rolling and slitting equipment from 1590 to the present time.

in cutter steels during the particular period in question. During the years from 1931 to 1936, when large tonnage orders for steel were scarce, the processing equipment in all up-to-date mills was improved and with it, the slitter, so that today, the coil strip slitter is as much a part of mill equipment as the tandem cold mill and the pickle line.

Some mill men ask why the slitting line cannot be brought up to the present day mill speeds and when the requirement for higher speeds becomes greater, this problem will face the slitter manufacturer. To analyze this problem, we must go back to that period when 75 to 100 feet per minute was considered a good speed for slitting and note from the many service reports that cutters, stripper fingers and guides were giving the most trouble. In other words, those parts coming in direct contact with the metal, were wearing more than a satisfactory amount. This was in the period between 1915 and 1925 when every slitter manufacturer was experimenting or had tool steel metallurgists experimenting to develop a cutter which would answer the purpose for higher cutting speeds. Electric furnace alloy steel gave alloys which could be used as cutters for speed as high as 300 feet per minute, when operating on low carbon strip with very little or no alloy and slitting speeds were improved to this extent by 1931.

During that period from 1931 to 1936, when every steel consumer was faced with the problem of reducing the cost of his product and the capital was not available to purchase new automatic forming and drawing equipment, the steel companies developed many higher strength alloy strip steels which could be used in these products in a lesser amount and thereby reduce the cost to the consumer's satisfaction. Although taken into consideration, steel mill equipment, which was built for the ordinary steel analysis, was put to test and slitting particularly suffered because it was in this period that the high carbon high chrome steels were just beginning their use in cutters and not every machine was equipped with them. The metallurgists again came to the rescue by further developing the high carbon high chrome steels which in an improved form are the popular cutter steels of today.

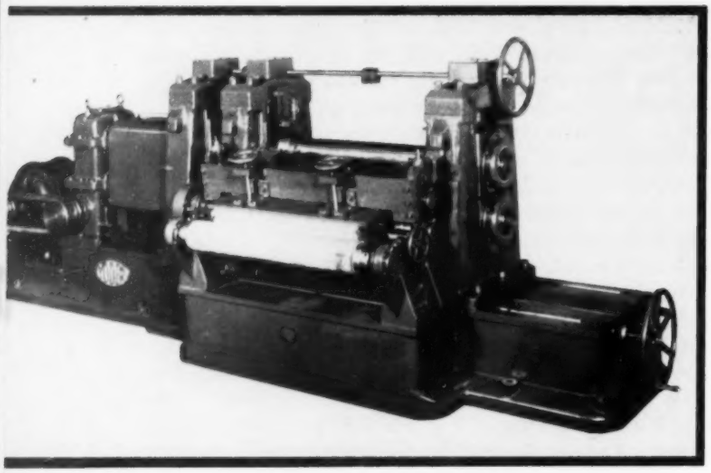
Today, the problem is the slitting of stainless steel, which in the one-half and up to full hard grades and in the hot rolled scaly condition are chipping the high carbon high chrome cutters and turning over cutting edges at 300 feet per minute much the same as the alloy steel strip acted on the tool steel cutters at this same speed some few years ago.

Comparing slitting speeds on various types of strip, it was found that heavy gauge slitters, when equipped with high carbon high chrome steels and operating on stainless steel at 300 feet per minute, gave the same cutter life as these same cutters operating at twice the speed on mild alloy strip and almost three times the speed on ordinary low carbon soft cold rolled strip. Cutting clearance is of vital importance in extending life and decreasing the possibility of chipping. Clearance should be the correct amount for each gauge on each set of cutting edges doing shearing. Experiments now being conducted indicate that carbide cutting edges may be the solution to this new problem but there is insufficient data on which to base an actual fact. So much for the cutter problem and more about the other problems involved.

Starting table guides on a strip slitter at higher speeds of 300 to 1,000 feet per minute are furnished in many forms such as replaceable bronze blocks, anti-friction bearing mounted rollers and large diameter discs on a billy roller. All these types must be adjustable over the full range of strip widths being fed into the machine and in the case of initial slitting or trimming on hot rolled mill edge strip must be quickly adjustable during operation to follow the edges of the strip which may vary as much as an inch and a half in the width during the length of a coil. This adjusting is of lesser importance since a great amount of the successful functioning of these parts depend on the operator, providing, of course, the machine is equipped with the easily accessible adjustment parts. This is to imply that automatic control of this adjustment has not as yet been found necessary and the possibility of its being imperative is quite remote. But guide life itself is still of considerable importance.

From actual inspection, bronze guides indicate considerable wear from one turn of operations and after 10 turns on some types of strip must be thrown away even though four working surfaces are provided by turning the guides over and around.

Roller guides on anti-friction bearings give the best



Rotary trimmer for tinned and coated strip. Speeds up to 600 fpm are not unusual.

life record, since they rotate with the strip and there is a minimum amount of abrasion. Also they may be turned upside down when grooves are worn in one end, to be used a second time. Life, depending on service, may be from 8 months to 2 years, figuring one turn a day operation on speeds as high as 500 feet per minute. A slightly shorter wear life is noticeable at speeds up to 1,000 feet per minute, although it does not follow as being directly proportional.

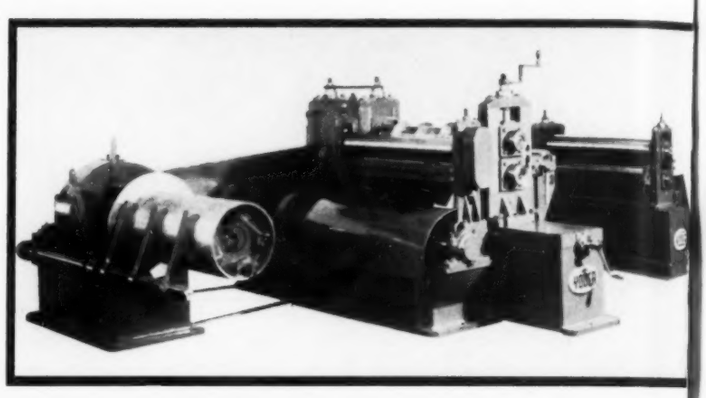
Discs on rolls are satisfactory for finish slitting on material which has two edges already trimmed and will give a good life record. However, they cannot be easily adjusted during operation and are not very popular for this reason.

One important point in the design of a high speed precision slitter is to provide rigid support for the arbors preferably mounting the bearings directly on the shaft necks and very accurately paralleling the cutter spindles, in both the horizontal and vertical plane. It follows that housings and such parts must be very rigid to maintain permanent alignment. A misalignment of a few thousandths in either plane will result in increased cutter wear, a wavering of the strip transversely in its passage through the machine which, of course, causes excess camber and makes the control of strip in starting guides more difficult and results in greater wear of these parts.

Hardened steel, bronze and composition stripper fingers do not give as good an account of themselves at high speeds as the oil soaked wood fingers now in more or less general use in the mills, although on sheet slitting the aforementioned types give the better service because they can be anchored in place more rigidly and the starting end of each sheet, which may be slightly curled, will not as easily cut and shave the working surfaces. Another reason for longer life on steel, bronze and composition fingers as applied to sheet slitters, is the reduced speed of these units as compared to strip work. This is not to infer that the aforementioned parts are the only limiting factor in accomplishing higher slitting speeds, for the general design of the equipment has a direct bearing on this as well.

Sheet slitters of course, cannot be speeded up beyond a safe handling speed for the operator and on units having capacity for $\frac{1}{16}$ in. gauge to $\frac{3}{16}$ in. gauge, the economical speed from operator and power standpoint, is about 200 feet per minute. On lighter gauge units down to, but not including tin-plate, the economical speed is approximately 300 feet per minute. For tin-plate, where an operator shuffles the blanks into the machine, 400 feet per minute seems to be a good speed.

Coil strip lines are somewhat limited by the handling equipment at each end as well as the controls applied, and although these cannot be mentioned in detail, it may be well to mention the various types now in use. Uncoilers in their various forms may consist of a cone



A medium gauge slitting line, using the drive slitting principle, with slip clutch recoiler; suitable for speeds up to 400 fpm.

type unit with simultaneously adjustable cone heads and equipped with hydraulic or screw lift loading buggy or the unit may have cone heads adjustable individually and equipped with elevating cones and stationary height buggy whichever an operating department may decide to be the more adaptable.

Manual or power expanding drum type uncoiling reels with elevating loading buggies or double swiveling type expanding drum uncoiling reels which may be crane loaded at intervals, when slitting is being carried out on a coil, work very satisfactorily. And last, but not least, the idling or driven roll coil suport box with manual or power adjustment on confining side plates may be applied where strip surface is scaly or pickle finish. Some installations working on high finish strip use cloth covering on the rolls of the coil box, however, the cloth tends to absorb oil and pick up small particles which, after a short time, will scratch high finish material.

On all types but the coil box, a light amount of back drag or tension may be developed on the strip either through mechanical or electrical means, and although this is not always desirable from a slitting standpoint, it does add stability to the strip on its entrance into the starting table guides.

The coil box will operate satisfactorily at speeds up to 300 feet per minute, but before this speed is reached,

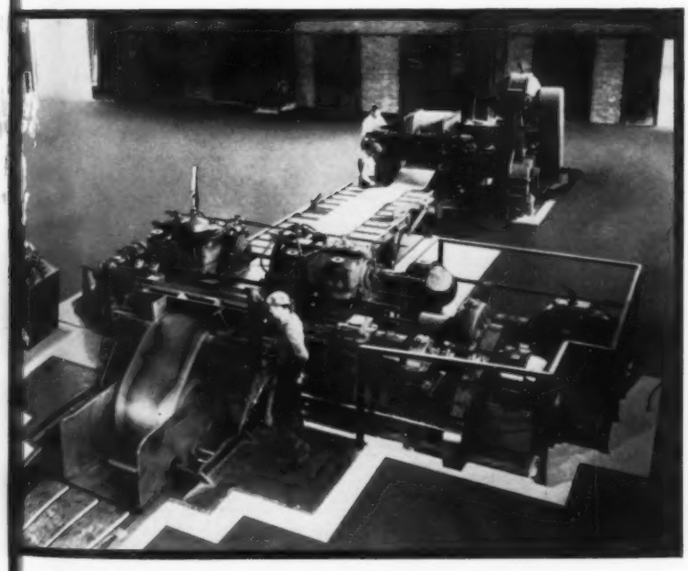
on the lighter gauges, the coil will, due to its un-uniform shape from previous handling, begin to bob up and down and sometimes go out of control pulling out the side plates or snag firmly and stall the entire line.

The cone and expanding drum type answer the purpose as a coil support for speeds up to 1500 feet per minute, providing the cones are a tight fit in the coil and coils are wider than the cone faces, so that the coil is held very rigid between the flanges and on the inside. Two advantages of the expanding drum type uncoiler are the fact that they may be made to expand over quite a range of inside coil diameters and will support coils from an extreme narrow width to the maximum strip width which may be handled in the line.

Scrap handling is also a problem on a slitting line, however, through the use of choppers, reels or ballers of properly designed types, a speed of 1000 feet per minute may easily be maintained. The scrap chopper is very popular for a single line installation where the gauge variation is not too great to be cut with one cutter clearance. The baller is used in conjunction with as many as eight lines, coiling scrap from all at one time and will usually be found installed in this way.

Recoiling equipment may consist of a multiple roll type, often termed a loose coiler, such as used on heavy plate or the manual or power expanding drum type as now used in most mills.

For speeds in excess of 300 feet per minute, the drum type unit equipped with power expanding and collapsing and lift or ram type unloading buggy has advantages over the roll type, one of which is the tension which may be developed to assist in slitting, and another, the material comes in contact only with itself after the first wrap on the drums, and the lesser number of parts touching the strip, the more remote is the possibility of scratching.



This strip trimming line includes a coil box, rotary trimmer, and multiple roll loose coiler.

In the slitting lines for operation on alloy, high carbon or stainless steel strip, much better slitting will be accomplished when a seven to eleven roll roughing leveler is inserted between the uncoiler and the slitter. This unit accomplishes sufficient flattening to insure more accurate slitting and a better control of the multiple strips coming from the slitter. Inserting a leveler somewhat complicates the control setup but more than pays for itself in the quality of work done and the ease with which the work is controlled.

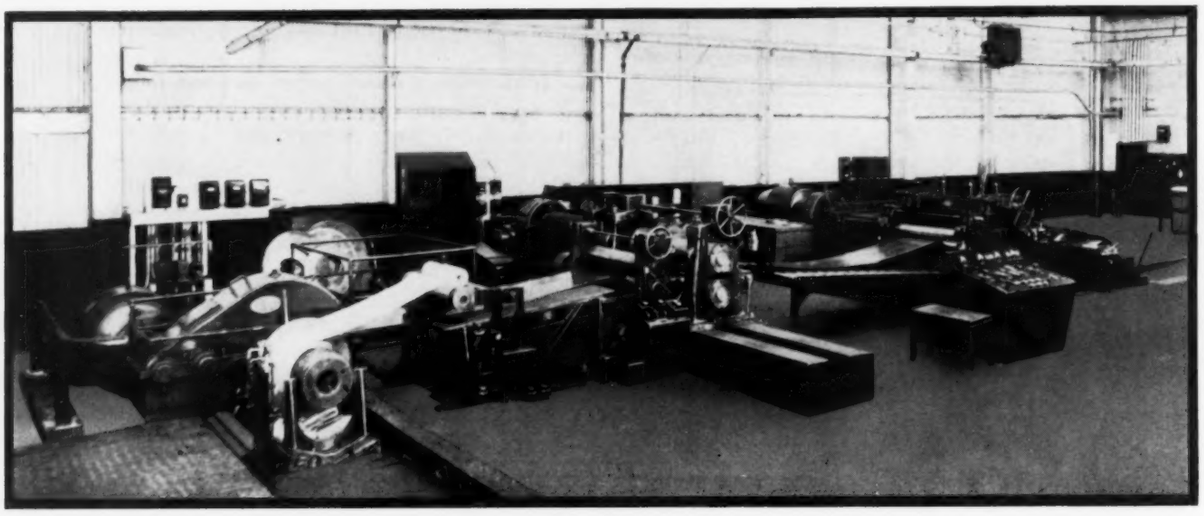
A great many problems in slitting arise from the great variations in gauges which must be handled and also the great variation in initial coil widths which must be run. This is particularly true in a cold mill furnishing finish slit strip to the consumer. For example, there are slitting lines in service having a top speed of 1000 feet per minute on gauges varying from .008 in. to .125 in. and widths at the feed end varying from 6 in. to 38 in. Also on this same equipment, strip types vary from soft cold rolled to half hard stainless.

The important problem to be considered is, should the equipment be designed to slit narrow strips of $\frac{1}{8}$ in. stainless at the 38 in. width or narrow strips in .008 in. soft cold rolled at 6 in. wide. Fortunately the demand for narrow $\frac{1}{8}$ in. gauge stainless is light and only a small number of strips must be made from the 38 in. width which can be run at 250 to 300 feet per minute and the equipment may be designed to run 1000 feet per minute on the lighter gauges, making a greater number of cuts.

This analysis of the problem may save the customer as much as 50 per cent in horsepower requirement and consequently in the weight of the machine and an incalculable amount in the savings on setup of a light machine, as compared to a heavy cumbersome unit which would have to be installed if the heavy, narrow strips were the deciding factor.

For control, there are various fundamental methods of operation used successfully today and these may in some cases be used in combination to save initial cost as well as operating cost. The oldest of these methods is drive slitting with slip clutch recoiling. This equipment may be used for speeds up to 400 feet per minute with an appreciably low maintenance cost on a clutch which has an asbestos lining. This method may be used over a wide range of gauges and widths when the clutch is the adjustable type and the recoiler may be driven from the slitter by roller chain or a separate motor depending on gauges and widths to be slit. There is no synchronizing problem here and the initial cost of the mechanical equipment is only slightly higher than the mechanical equipment of a duplicate line designed for use with some type of electrical control.

The second method is variable voltage with tension regulator control which until the introduction of the newer types of regulators would not handle a range of 4-to-1 in gauge with 3-to-1 in width without hitting a medium in which some of the lighter and some of the heavier gauges were not slit under the best conditions. The matter of matched motors is still somewhat of a problem on variable voltage lines, however, the synchronizing of various size motors in a line has been carried out with a great degree of success through the



A leveler between the uncoil box and slitter increases slitting accuracy and gives better control of the strip.

addition of certain parts in the electrical control. The WR^2 of all drives and rotating parts must also be carefully considered from the standpoint of acceleration, particularly when operating over a large speed range. At present, with modern controls and regulation, total variations in width amounting to approximately 16 or 20-to-1 may be handled under the same conditions as the 12-to-1 variation with older types of control and regulation, and if the variation is less, the ideal will be more nearly reached.

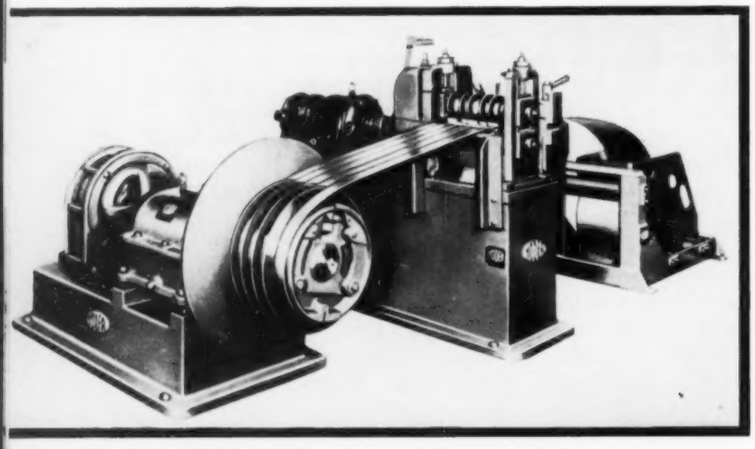
The third method which in recent years has been developed to a point of popularity is pull slitting, wherein the slitter is equipped with a driving means sufficient only to thread the material to the recoiler. After once gripping the ends of the strips in the slot provided in the drum, the slitter motor is disconnected and the total power required to slit is derived through tension developed by the recoiler. It must be noted that the third method differs from the first two in that speed in this case, is directly proportional to coil buildup and if the initial speed is 300 feet per minute and the coil buildup is 3 to 1, the final speed will be 900 feet per minute or an average speed of 600 feet per minute actual production.

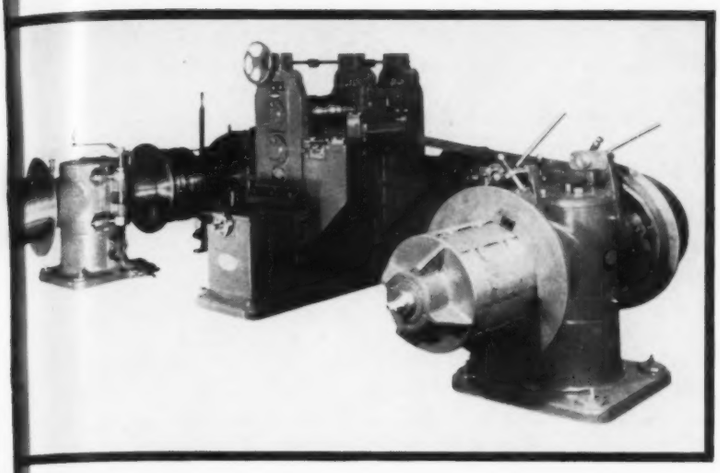
Pull slitting has been done in some plants at speeds up to 1500 feet per minute which with a 3-to-1 coil buildup gives an average speed of 1000 feet per minute, the only differences between this and a variable voltage line at 1000 feet per minute speed is the cost of equipment and the range of gauges which may be handled on each. A line doing pull slitting should be designed for a narrow range in gauges so that the slitter will remain small and will induce a minimum amount of back tension due to friction and inertia. Also, the number of cuts in each particular gauge must be carefully examined to assure that tension on the cutters will be sufficient to overcome this inertia and friction and avoid tearing.

Experience in the various mills now using pull slitting indicates that when this method is properly applied it produces the most desired edge and to accomplish work on a line over a wide range of gauges the pull slitting principle in combination with the variable voltage gives a very economical setup. The heavier gauges from .025 in. to .078 in. to .093 in. may be pull slit at speeds up to 1500 feet per minute while the very light gauges (.025 in. down) may be slit through variable voltage control at a constant speed of 1500 feet per minute. In this way the equipment may be designed for the heavier gauges without detrimental action to slitting on light gauges.

The fourth method of control is drive slitting and recoiling through an eddy current clutch, which in cases of light slitting lines up to No. 16 gauge by 30 in. wide handling a minimum .015 in. gauge by 30 in. wide strip, give much the same action as variable voltage control insofar as smoothness of operation. When this type of control is used, the WR^2 of the clutch parts and drive parts of the recoiler must be carefully ex-

This small pull slitter includes a coil box, slitter, and recoiler.





This pull slitter, with double swivel uncoiler and recoiler, gives high production.

amined to determine acceleration characteristics as compared with the slitter—particularly when operating on the lightest gauge and narrowest width. There are, of course, other methods of control which have been used with some degree of success on the lower speed equipment, but as slitting speeds increase they have become less popular and it will not be surprising to find some of the aforementioned methods discarded when slitting speeds are increased further.

In closing, there is one thought to be left with everyone interested in slitters. The equipment in a slitting line should be designed to do the particular work for which it is intended—taking every gauge and width into consideration, so that oversize, unwieldy parts do not hamper setup and interfere with its operation.

DISCUSSION

PRESENTED BY

R. A. GEUDER, *Manager,* Metal Industry Applications, Reliance Electric and Engineering Company, Cleveland, Ohio

H. W. POOLE, Industrial Engineering Department, General Electric Company, Schenectady, New York

G. A. CALDWELL, Industrial Engineering Department, General Mill and Resale Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

GEORGE KENTIS, *Sales Engineer,* The Yoder Company, Cleveland, Ohio

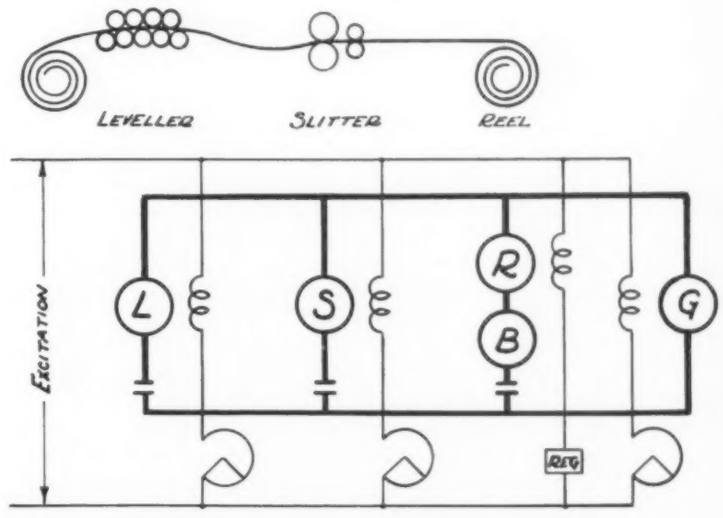
R. A. GEUDER: In the application of electric motor drive to a modern slitting line, many factors must be considered, such as:

1. Maximum gauge
2. Maximum number of cuts
3. Maximum width of stock
4. Maximum tension for a good coil
5. Maximum fpm for maximum gauge
6. Minimum gauge
7. Maximum tension for minimum gauge
8. Maximum fpm for minimum gauge
9. Coil build-up
10. Kind of electrical power available

With these facts before us we can proceed with an intelligent selection of equipment. Sometimes not all of the desired data is available so that someone must draw on his experience to round out the list of motors and control. Many of the first slitting lines designed with variable-voltage control for acceleration, deceleration and lineal speed range did not take advantage of a combination of voltage control and motor shunt field control. In other words the electrical equipment was designed to handle the heaviest material at the maximum speed. This procedure did not inflict a particular economical burden because the equipment was all somewhat small.

However, as the advantages of variable-voltage control became more and more evident, its application reached into the heavier "slitting lines" where horsepower capacities began to take on real proportions. At this time the study of heavy loads at lower speeds and the same or lighter loads at higher speeds indicated a modification in motor application. The result was the combination of variable-voltage and motor shunt field control to obtain a combination of constant torque and constant horsepower. Interesting enough this method provides a smaller motor-generator set with its lower

Diagram showing simplified wiring scheme for slitting line.



cost and is associated with an overall reduction in control cost.

By way of interest, this somewhat typical "line" was developed. The facts were:

1. .093 to 3/16 in. gauge (hot rolled)
2. 40 in. wide (maximum)
3. Tension range 5000 to 16000 lb.
4. Coil build-up 20 in. to 50 in.
5. Speed range zero to 240 fpm.
6. Leveler precedes slitter requiring maximum horsepower at 150 fpm on maximum gauge.

Conclusions:

1. Leveler motor capacity predetermined.
2. Slitter motor capacity selected first to provide sufficient "hold-back" for good tension when only sidetrimming; second, sufficient capacity to slit stock with maximum cuts before tension helps.
3. Reel motor capacity predicated on producing maximum tension at 150 fpm. Lighter gauges handled at higher speeds resulting in same or less horsepower. Field range for build-up and partial lineal range.
4. Speed range of line obtained by combination of variable-voltage and field control. Generator size determined by levelling load plus slitting load plus electrical and mechanical losses in slitter and reel drives. Booster generator used to compensate for IR drop differences between slitter and reel motors. Note that the reel may help the slitter motor.

H. W. POOLE: Mr. Kentis has given us an excellent account of the development of the slitter and the slitter line as we know them today, and in doing so has touched upon the various methods of operation and the selection of motors for driving the slitter.

First of all, let me reaffirm Mr. Kentis' statement that a thorough analysis of the operating requirements of the mechanical equipment and the proper coordination of the mechanical and electrical equipment are of major importance. Too many times a piece of mechanical equipment, such as a slitter, is purchased without consulting the electrical department and in the process certain requirements are set up for the electrical equipment— requirements which are neither entirely necessary nor economical when the overall picture of both the mechanical and electrical equipment is considered.

This condition has existed to a far greater degree in the past than it does today and much of the credit for the change is due to the mill builders and machinery manufacturers themselves. Being in a position to fully appreciate the importance of coordination of mechanical and electrical equipment and having profited by past experience, these people are consulting the electrical manufacturer with regard to their designs and their requirements, and are thus able to present to the mill man a much better comprehensive picture than ever before.

Mr. Kentis specifically mentioned savings in hp requirements when the proper analysis is made. This, of course, involves the question of constant horsepower and constant torque drives. This is not the time for a discussion of these drives, but I do wish to point out that the electrical equipment may be of the variable voltage type and still have constant horsepower characteristics over the required portion of the speed range if this requirement is known in advance and is taken into account when the selection of the electrical equipment is made. This is a characteristic which is almost always made use of in cold strip mills, but one which is too often overlooked in the consideration of auxiliary drives.

Mr. Kentis mentioned four fundamental methods of operation or control of slitters and recoilers or winding reels.

He mentioned power or drive slitting with the recoiler driven through a mechanical slip clutch. This method has been used extensively in the past and is still used somewhat today, but naturally the electrical manufacturer feels that he can offer a better type of drive for the recoiler and one which will pay for itself in decreased maintenance and greater tonnage over a period of time.

Next mentiond was variable voltage control with a tension regulator on the reel. The use of variable voltage control does not necessarily require the use of an automatic regulator of any kind although its use is certainly to be desired. In the past many mills have installed rider roll rheostats to compensate for the reel build-up and to maintain a fairly uniform speed of the strip through the slitter knives. Rider roll rheostats will work and there are isolated cases where they will do the job as well or better than other devices, but in most cases of high speed processing lines where ease of operation, accuracy, and quality of product are important, they should be and today are regarded with disfavor.

The electrical manufacturer is usually on the spot when the question of rider rheostats vs. regulators is being discussed. He cannot usually make a flat statement that the rider will not work, but in most every case the installation of the rider proves unsatisfactory from one standpoint or another. Fortunately, the initial cost of the regulator today is so near the combined cost of the rider rheostat and its operating mechanism that few installations of the latter are made.

Before leaving this one method, however, I wish to point out that the regulator is not always a current or tension regulator. In many cases, the design of the mechanical equipment is such and the range of tensions required so high that other factors may dictate the use of a speed regulator or some sort of automatic loop control, if a loop is involved.

The third method which Mr. Kentis mentioned was "pull slitting". This seems to be a subject upon which no two mechanical men can agree 100 per cent, and most certainly therefore is not one upon which the electrical man should take sides. It will suffice to say that in many cases the electrical equipment can be designed to change from pull slitting to drive slitting by the adjustment of a rheostat.

The last method mentioned, that of drive slitting with the recoiler driven through an eddy current clutch, has been used successfully on some installations, but usually is not as flexible as the separate d-c motor drive where inertias are easier to control and boosters may be added for forcing during acceleration and deceleration.

G. A. CALDWELL: Mr. Kentis' paper on slitting has been very interesting and after listening to a paper that is presented primarily to bring out the mechanical features of a slitting line, the electrical manufacturer

has a better background to properly apply the electrical equipment required. Mr. Kentis has outlined the various types of control which can be used for a slitting line and it is apparent that each scheme has its particular field.

It seems to the writer that the first, second and fourth methods are more adaptable for the slower speed lines, and for those handling the lighter gauges. We know that the friction clutch requires considerable maintenance at high speeds and high torques and also involves considerable power loss. I also believe that there is a tendency to lose tension in the strip between the reel and the slitter during acceleration especially when there is a wide range in the tension adjustment required, and when the friction device is set for a light tension. There is also a variation in tension as the coil diameter builds up since the clutch is essentially a constant torque device.

Pull slitting certainly simplifies the electrical equipment and is especially attractive to the customer who wishes to have an inexpensive slitting line which he can use to obtain a wide range in strip widths and still carry only a small stock of strip steel.

As usually applied, the pull slitting line operates at a variable line speed with an a-c driving motor on the recoiler and the speed varying as the diameter of the coil changes. In other cases a d-c adjustable speed motor is used for the reel motor and the operator maintains approximately constant slitting speed by means of a hand operated rheostat.

When it comes to the more elaborate slitting lines operating at high speeds and designed for a considerable range of product, the third method is the one usually selected. Most of these lines are equipped with levelers or similar devices which means that the speed of the strip has to be synchronized in traveling through the various devices, also the slitter handles a sufficiently wide range in product that under some conditions pull slitting is desirable and in other conditions it is desirable to have a considerable amount of power applied to the slitter itself.

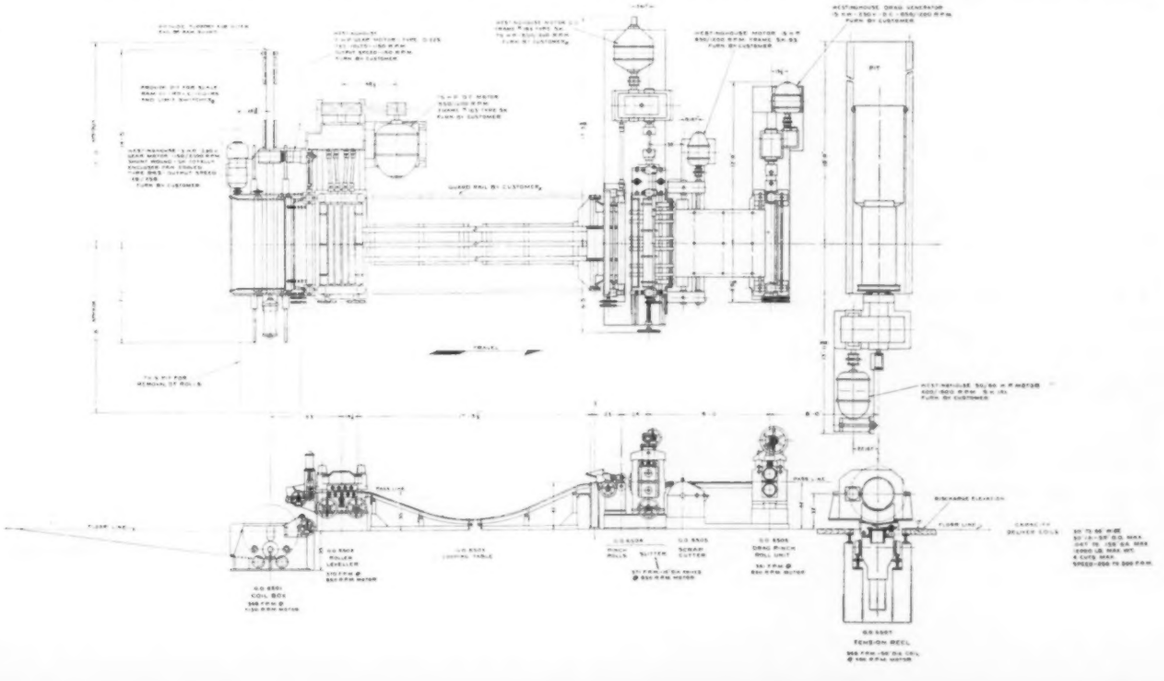
A typical slitting line of this type is shown in the accompanying sketch. This line consists of a coil box, roller leveler, slitter, scrap chopper, drag pinch roll unit and the tension reel. It is desirable to maintain a loop between the uncoiler and the slitter as an aid in guiding the strip into the clitter and therefore these two motors must remain at a constant relative speed and the reel motor must change its speed to compensate for the change in diameter on the reel.

This line is also equipped with a unit called a drag pinch roll that is not usually found in a slitting line, but it adds considerably to the flexibility of the line. With the line running at a given speed, manipulation of the rheostat in the shunt field of the motor can cause this unit to operate either as a motor or as a generator. When the unit operates as a motor it is in effect helping the reel to pull the steel through the slitter and thus reduces the tension between the drag pinch roll and the reel. If the drag pinch roll is operated as a generator then it in itself does not pull against the slitter but compels the reel to pull against both the pinch roll and the slitter.

It is conceivable under certain conditions that you might want to do practically all of your slitting by the so-called pull method and yet not wish to have excessive tension on the strip being wound on the reel as it might produce a too-tight coil. Under this condition the drag pinch roll can be used to pull the strip through the slitter and thus relieve the tension between the drag pinch roll and the recoiler. On the other hand the case may arise where the opposite effect is desired. This would be where it was desirable to do practically all of the slitting by means of power input to the slitter and yet at the same time the operator wished to have a tight coil, and to obtain this tight coil might require almost enough tension to pull the steel through the slitter as pull slitting. By forcing the drag pinch roll unit to operate as a drag generator it is possible to run with a loop between the slitter and the drag unit.

In normal operating practice, it seems that the best results are produced by a combination of power and pull slitting, and with the variable voltage type of control supplied with its control desk and indicating

Diagram of slitting line consisting of coil box, leveler, looping table, pinch rolls, slitter, scrap cutter and tension reel.



meters, the operator has at his finger tips a means of adjusting from power to pull slitting to produce the best edge. It is the writer's opinion that this is the type of control that will become generally popular as these lines develop in speed and range of material handled.

A slitting line such as the one just described should not be considered as an easy job and in comparing them to other types of processing line such as shearing lines, cleaning lines, galvanizing lines, etc., I believe that when considered on the basis of all these types of lines operating at the same speed, the problems of successful operation of a slitting line are as great or greater than any of those mentioned. I judge from the comments made by Mr. Kentis that this is true from a mechanical standpoint as well as an electrical standpoint. I would also like to issue a word of warning in expecting the impossible in wide ranges of tension in the recoiling unit. If the maximum tension and the speed is such as to require a 50 hp motor then all of the mechanical parts, etc. must be made sufficiently heavy to exert the pull and torques required. Now if a 10 to 1 range in tension is expected it means that the tension load on this 50 hp drive is now only 5 hp. We all know that it will probably take 5 hp of input at the motor at maximum speed to simply run the recoiler without any tension and that also the horsepower input to the motor will vary with the speed of the motor. If we assume that this change in horsepower input results in only a 5 per cent error from an empty to a full coil when operating at 50 hp, this same error will result in approximately a 50 per cent change when trying to operate at light tensions. It is also evident that it is much more difficult to try to maintain this tension during acceleration and deceleration as well as during the running condition when you are trying to control the inertia effects of a 50 hp drive when doing a 5 hp job.

On one installation where a wide range in tension accurately controlled was required, two reels were supplied, one large reel with a large motor for the heavy gauges and a small reel and motor for the light gauges.

GEORGE KENTIS: Mr. Geuder covers very well the type of electrical control as applied to many of the steel mill slitting lines now in operation. From observation of performance characteristics on some lines, there is a flexibility in this type of control which gives the operator all the desired acceleration and deceleration characteristics yet maintains tensions and speeds within the required amounts. When units other than the slitter and recoiler are added to the line, it does not complicate the control to any great extent and the additional units may be easily synchronized through proper rheostat equipment. It might be said that the combination variable voltage and field control setup has a wide field of application in those places where slitting on a wide range of gauges and strip widths is desired and when properly designed will be economical in first cost and in operation.

Mr. Poole makes mention of the desirability of a thorough analysis of the operating requirements of the mechanical equipment before proceeding with the control design. This is one of the most important phases of slitter line design and many lines have been penalized in their operation due to this one factor.

In one particular line where the control was not designed to suit the mechanical equipment or if you will (vice versa) the acceleration periods and deceleration periods were erratic to such an extent that strip was being jerked through the knives or looped between the recoiler and slitter.

When a line of this type is once installed, it is a very expensive problem to iron out these difficulties without a complete redesign of the mechanical or electrical equipment and often it is a difficult problem to determine where to begin this redesign when the equipment is once installed. There is so much to be gained by a small amount of design work when the line is in the early stages of discussion that this one point should be brought to the attention of those contemplating the installation of new equipment of this type.

Mr. Caldwell discusses the present slitting line problem very thoroughly—particularly the type of line having a wide gauge and width range which correspondingly necessitates a thorough study of the various tensions and slitting horsepowers to handle the various gauges and widths. In the past, the mills have been confronted with a problem of furnishing finish slit width strip to the consumer; but as long as the cutomer was satisfied to purchase his own slitting equipment or have the strip slit in some other customers' plant or steel warehouse, not too great an effort was made to install equipment for the customer's requirements.

At present, however, the mills have given consideration to furnishing finish slit strip to customers and the problem is greater at the mill which have a wide variety of widths to furnish in a great many gauges. Present trends of slitting are toward the pull slitting principle with design features of the mechanical equipment so that variable voltage may easily be added. This method assures the mill a beginning at production slitting without too great an outlay for electrical equipment and in most cases will save as much as forty per cent in the initial installation cost.

During the first few months of operation, the operator can become acquainted with the mechanical equipment which with pull slitting is very simple to control and when the time for the variable voltage system to be installed has been reached there will be very little further education required. Also, the slitter as built will most probably be equipped with an over-running or disconnect clutch to do pull slitting and many gauges and widths may continue to be slit on the pull slitting principle with the most difficult jobs to be run on variable voltage.

With these various items in mind, there may be food for thought on slitting equipment now being contemplated and as Mr. Caldwell mentioned, there are various ways and means which can be utilized to assure a satisfactory operating slitting line within certain limitations.

WOODY FRACTURES

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This report is the result of investigational work sponsored and financed by the Association of Iron and Steel Engineers as an educational project of its Philadelphia District Section. Mr. Kulp, who is now in the metallurgical department, Steel and Tubes Division, Timken Roller Bearing Company, Canton, Ohio, was formerly connected with Lukens Steel Company, Coatesville, Pennsylvania.

▲ THE nick-break test has been used for many years as one method of determining the degree of homogeneity of steel plates. Samples in the "as-rolled" condition are nicked and broken at room temperature by press, sledge or power hammer. The resultant fracture faces are examined for irregularities such as laminations, inclusions, pipe or blowholes.

The 1939 Metals volume[1] of the American Society for Testing Materials lists the nick-break test for firebox quality plate in eight regular specifications and in one tentative specification. The wording is similar in each specification (except for plate sizes) and a condensed version follows. The object of the homogeneity test is to open and render visible to the eye (magnifying glass may be used) any seams due to failure to weld up or to interposed foreign matter or any cavities due to gas bubbles in the ingot. One of the fracture faces is examined and the plate may be rejected if any single seam is found more than:

(a) ¼ in. long for plates ¾ in. and under in thickness,

(b) ⅜ in. long for plates over ¾ in. and up to 4 in. inclusive in thickness,

(c) ½ in. long for plates over 4 in. and up to 6 in. inclusive in thickness.

The test may be made on a broken tension test specimen, first grooved 2 in. from the square end with each succeeding groove about 2 in. away and on the opposite side from the preceding groove. At least three nicks or grooves should be made on each test and for plate thicknesses

(a) ¾ in. and under, a nick about 1/16 in. deep shall be made

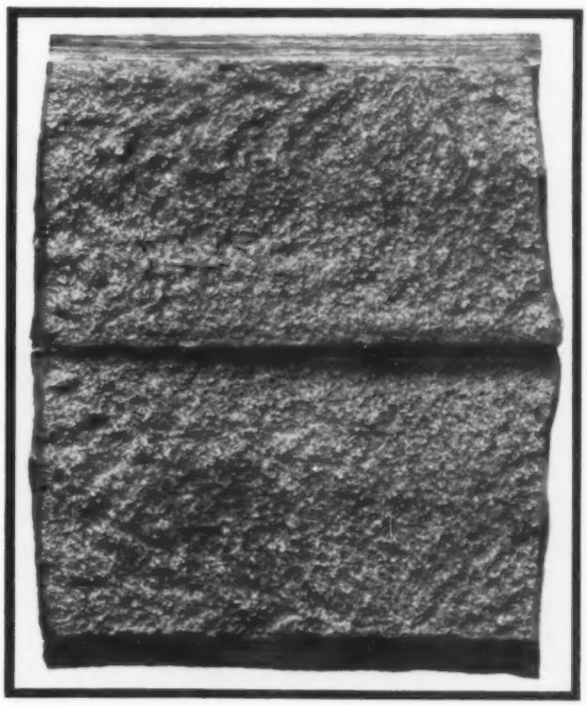
(b) over ¾ in. and up to 2⅛ in. inclusive, a nick about ⅛ in. deep shall be made

(c) over 2⅛ in., grooves may be cut at one place on both sides to leave a fracture which will include the horizontal axis of the plate and have a face at least 2 in. in depth.

The specimen can be broken at succeeding grooves with either a hammer or a press, the bending being away from the groove. These specifications allow a wide latitude in fracture quality, a point which is fully discussed in later sections.

The nature of the fractures resulting from the nick-break test may vary greatly in appearance and many descriptive terms have been used to designate the types of fracture. A primary classification should include three types, granular, woody and defective. The granular (or crystalline) fracture surface has a shiny, metallic appearance and is relatively smooth. The woody frac-

Figure 1—Sample E 11. Granular fracture.



ture surface is dull gray in appearance and rougher and more ragged than the crystalline fracture. Often a fracture exhibits both the crystalline and the woody structures in different areas of the same face. A defective fracture is one which exhibits pronounced leafing or ledging due to the presence of unwelded blowholes, laminations or large inclusions. The area in the region of the seam or crack is usually woody and the balance of the fracture surface may be either granular or woody.

A seam-free granular type of fracture is considered most desirable in the average nick-break test. Defective fractures, being indicative of segregated non-metallics, are properly a basis of plate rejection. The significance of woody fractures has not been well understood and the disposal of plates exhibiting this type of fracture has often been open to question. Some inspectors have rejected on the basis of woody fractures and others have taken the attitude that such steel should be judged satisfactory until the significance of the fracture is better understood.

The rejection of woody fracture steel has raised a justifiable point of dispute because the conditions of the nick-break test have not been rigidly defined and because the relatively little knowledge of the cause and of the significance of this type of fracture is largely controversial.

In an effort to augment and to clarify the knowledge of the subject, the present investigation was undertaken to determine insofar as possible:

1. The effect of the variable factors of the nick-break test.
2. The cause of woody fracture.
3. The significance of woody fracture.

LITERATURE REVIEW

A major portion of the writer's time at Lehigh University was spent in literature research on the subject of the nick-break test and the types of fracture resulting from the test. The primary source of references was the book, *Bibliography of Non-Metallic Inclusions in Iron and Steel.*[2] In addition the following sources of references were used:

(a) Abstracts of the *British Iron and Steel Institute*
(b) Abstracts in the periodical *Metals and Alloys*
(c) Engineering Index
(d) Industrial Arts Index
(e) Technical publications of A.S.M. and A.I.M.M.E.

In many instances the references given in one pertinent article led to other papers on the same subject. Several of the original articles were not available and in these instances, statements are based on abstracts of the original.

The review of the literature was difficult because of the somewhat justifiable confusion found in terminology. Fractures other than "granular" or "crystalline" may have many different appearances and the writers used terms descriptive of the particular types of fractures with which they were working. Translator's interpretations of descriptive words found in foreign publications add to the confusion. A list of terms encountered and sometimes used interchangeably in the literature include the following: woody, slaty, spongy, foliated, leafy, ledged, stepped, amorphous, fibrous and

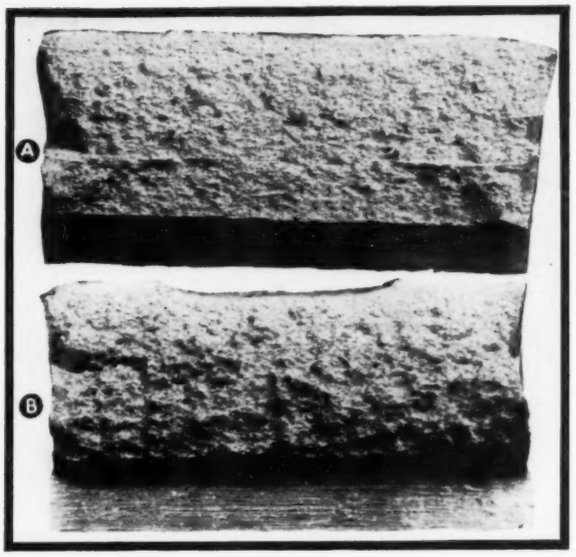
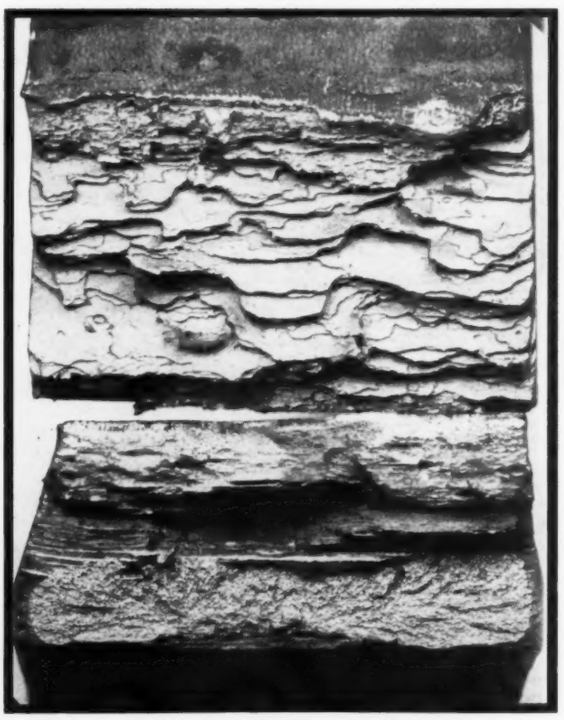


Figure 2—*A*—Sample C 5. *B*—Sample C 6. Woody fractures.

descriptive combinations of the foregoing. The more prominent of the different types of fractures found in the present investigation are described in Section III. The following discussion applies to the contrast of granular and of woody, fibrous or defective although one cannot accurately use the latter three terms synonymously.

Figure 3—Sample F 12. Leafy fracture.



An attempt has been made to correlate and to list statements in some logical order rather than to consider each article individually. In order to avoid repetition, the names of the writers have been omitted and references to the bibliography are given. The statements may refer either to the text of an article or to discussion related to the article.

A majority of the papers dealt with the causes of fractures other than granular and covered a wide range of practices. A list of these causes is given below:

1. Making of steel on basic bottoms.[3 4]
2. Rusty scrap or oxidized charge, particularly turnings.[5 6]
3. Clean scrap and two oxidizing slags (on electric arc furnace to produce fibrous metal).[7]
4. Addition of scale to the acid open hearth bath.[5]
5. Non-metallics (not sulphides) caused by poor (melting) furnace practice.[8]
6. Temperature conditions in furnace during manufacture of steel[9] including superheat of the melt.[10]
7. Excessive use of aluminum in killing mild steel.[3]
8. Condition of molten metal and conditions of solidification.[11]
9. Dendritic segregation[6], selective freezing[11], crystal segregates[10], and segregated alloying elements.[12]
10. Tar mold wash.[13]
11. Pressure of small CO blowholes originating from oxides contained in the steel.[14]
12. No differences found in gas content ($H_2O_2N_2$).[8]
13. Chemical composition, in particular, high C[9], low Mn[11], Ni and Cr[3], and high alloy content.[9]
14. Non-metallics[9], sulphides parallel to direction of rolling[15], and basic (44 to 52 per cent CaO and MgO) inclusions.[3]
15. Unyielding, hard non-metallics having explosive effect on surrounding steel during rolling, causing hairline cracks.[4]
16. Flow of metal during hot working[11] and amount of hot working.[9]
17. Cured or improved by prolonged soaking[3 5], careful forging at 1750 F[5] and by high forging temperatures.[9]

Several investigators[5 8 11] stated that little difference could be found between granular and fibrous fractures on regular metallographic examination, particularly with regard to non-metallics. Others[11 12 16] have indicated that banding or slag fibers readily distinguishable under the microscope have caused fibrous fractures. Tests used included the stepdown[8], sulphur printing[15], cupric reagent etch[12], and macro-etching[11]. Woody fracture steels have a finer grain than those exhibiting granular fracture[8].

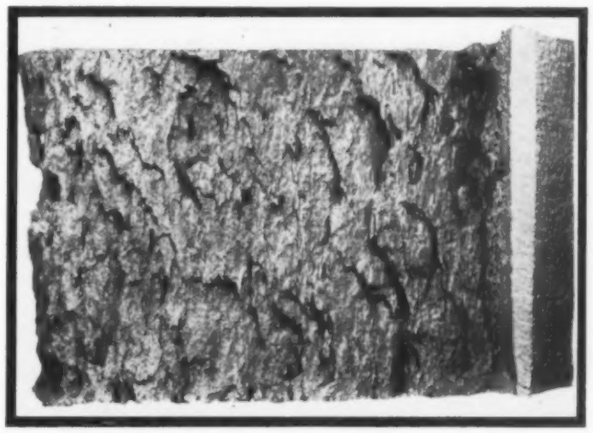


Figure 5—Sample D 8. Very leafy.

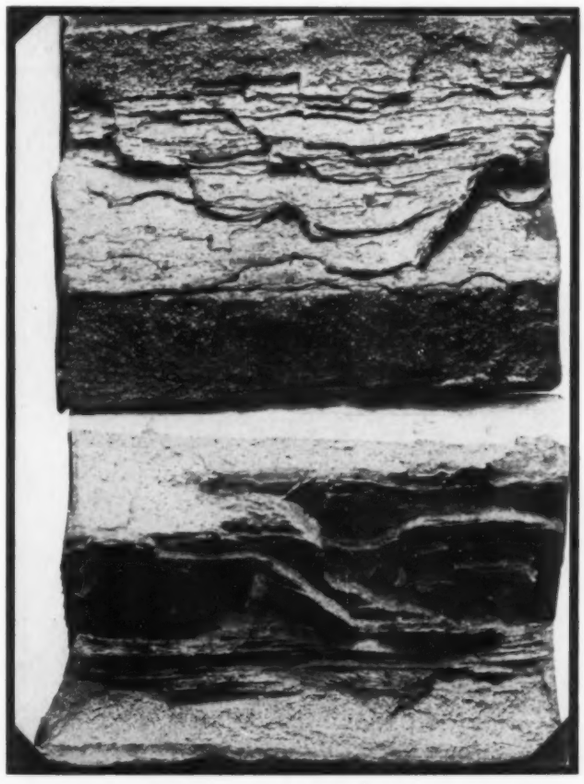


Figure 4—Sample D 13. Leafy center.

Few investigators have reported on the comparative physical properties of granular and of woody fracture steels. The elastic limit and ultimate strength are identical[8 11 17]. Woody structures radically impair longitudinal physicals[3]. Elongation and reduction of area favor fibrous[8]; elongation and reduction of area favor granular[11]. Impact values are higher on fibrous[8 11]. Fibrous fracture indicates toughness rather than ductility[11].

Little has been written concerning the effect of variables in the testing method. The factors stipulated by the American Society for Testing Materials have been outlined in the preceding section. The neck-break test has been used many years and one paper[18] describes early methods of testing. An old investigation[20] on testing method and mechanics of breaking led to vastly different theories than those entertained today. The breaking of a circular steel disc has been recommended to determine steel quality[19]. The difference in rupture between granular and fibrous fractures has been described[11]. One article[16] classified types of fractures,

measured breaking loads and determined the effect of temperature. One investigator[17] stated that plates over 20 mm in thickness broke with a granular fracture and that the nature of the fracture depended on the method of breaking.

Any proper interpretation of the significance of the fracture as indicated in the literature is almost impossible because of the differences in type of steel and in application for the steel. For example, some writers regarded fibrous steel as undesirable whereas others discussed applications on which such steels are specified. It is interesting to note that in contrast with the present general preference for granular fractures, one recent paper [16] regarded such fractures as an indication of undesirable brittleness.

The literature survey indicated that material on the subject of woody fracture is confused and is none too complete. However, as one grows increasingly familiar with the problem, it becomes apparent that many of the articles and the discussions published with them merit careful study. A majority of the investigators agree that the real cause of woody fracture is lack of homogeneity. This condition is usually caused by nonmetallics which are:

(a) present in the metal during teeming,
(b) segregated during solidification and
(c) usually elongated in the direction of rolling during hot working.

TYPES OF FRACTURES

During the investigation many different types of fractures were encountered. As was stated in the preceding section, attempts to describe the fractures lead to confusion in terminology. Therefore the number of classifications will be held to a minimum.

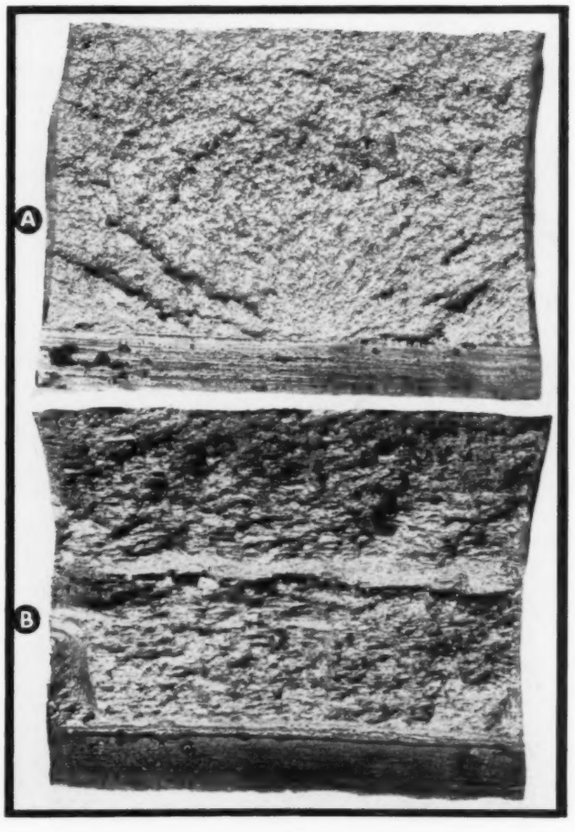
One experienced with nick-break testing can usually differentiate between the granular and any other type of fracture simply by the characteristics exhibited by the metal in rupturing. (This is particularly true when the testing is done on a hydraulic press.) Steel exhibiting a granular fracture ruptures with little noticeable deformation. A sharp report or snap can be heard when the break occurs. The characteristics of the rupture indicate brittleness or possibly stiffness. The faces of the fracture are relatively smooth and have a silvery, clean, metallic appearance. The term "crystalline" has also been used to describe this type of fracture but the writer prefers the term granular. Figure 1 shows the matching faces of a typical granular fracture on sample E 11*.

Steel exhibiting a woody fracture ruptures slowly and only with or after pronounced deformation. The faces of the fracture are of a dull, sometimes dirty, gray color. The surface is rougher than that of the granular fracture and may contain many small pockets, tubes or fissures. Duma[3] differentiated between woody and slaty fractures but the illustrations in Thum and Holdt's paper[16] indicate that their slaty fracture is similar to that herein described as woody. Figure 2 shows faces of typical woody fractures encountered on samples C5 and C6 by slowly breaking them in a press.

Steels exhibiting a leafy fracture rupture in much the same manner as the woody fracture steels except that the amount of bending accompanying the actual rupture is usually greater. The faces of the fracture are very ragged, the leafing or ledging is pronounced and large cracks or fissures may be developed between the leaves. The color of the fracture is usually of a darker gray than that found with woody fractures. The terms ledged, laminated, foliated and in some cases, fibrous, might also be applied to this type of fracture. Leafy fractures are shown in Figures 3 and 4, samples F12 and D13 respectively. Note that in the case of both samples part of the area near the rolled face is granular and that the leafy condition occurs in the center of the sample. Figure 5 illustrates a uniformly leafy fracture which occurred when sample D9 was broken in a press.

The writer hesitates to assign the term fibrous to any of the fractures shown in this report. The term leafy is sufficient to describe most of the badly defective fractures. In most cases the condition is due either to laminations or to inclusions that have been elongated during rolling to give a mechanical fiber structure in the metal.

Figure 6—Sample D 9. *A*—Press break. *B*—Hammer break.



*The letter refers to the heat designation and the number is one assigned to a sample for purposes of identification. Table 1 contains data on analysis and deoxidation practice. Table 2 contains data on test position, sample thickness and nature of fracture. All data tables and illustrations are contained in the appendix.

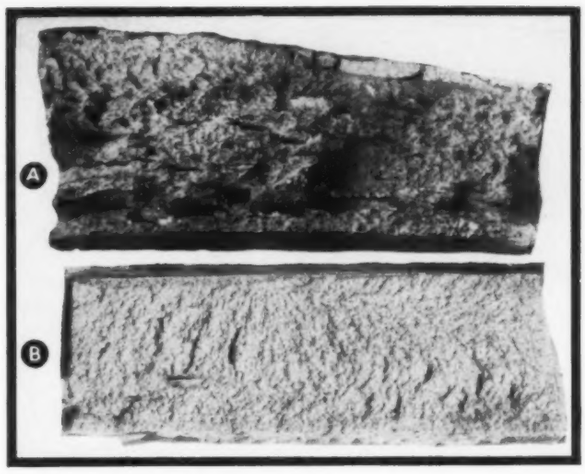


Figure 7—Sample F 14. *A*—Press break. *B*—Hammer break.

In this report the discussion will deal mainly with the three types of fractures described above.

The granular fracture is that usually preferred. Such fractures, however, may be defective if seams due to laminations, inclusions, or unwelded blowholes are sufficiently large. Such seams may (Figure 7) or may not (Figure 40) be accompanied by a localized woody area.

Woody fracture is that characterized chiefly by the gray color and rougher surface as contrasted with the crystalline appearance of the granular fracture.

Leafy fractures are ragged, ledged breaks usually indicative of segregated non-metallics.

PRELIMINARY EXPERIMENTS

When the problem of woody fractures became important at Lukens Steel Company, data studies were started and a number of experiments were made over a long period of time. Woody fractures occurred mainly in silicon killed alloy steels and in plain carbon steels which were aluminum killed in the molds. If a plate had any tendency for woody structure, this structure could be found in samples taken from a middle bottom transverse position in the plate. This indicated that the condition might be correlated with conditions in the bottom cone of the ingot and that the cause might be in either open hearth furnace or pit practice.

Extensive date tabulations were made in which such items as materials charged, melt down carbon, furnace finishing additions, residual manganese and tapping carbon, ladle additions, pit practice including mold size, and final analysis were listed in order of quality as determined by the nick-break test. No correlation of the occurrence of woody fracture could be made with any of the items.

Items of practice were then arbitrarily changed in an effort to eliminate woody fractures. Some of the experiments are listed below:

1. Varying methods of deoxidation ranging from use of excess deoxidizer in the furnace to tapping the heat open and deoxidizing in the ladle.
2. Top versus bottom pouring.
3. Use of double runner bottom plates for aluminum killing of large ingots.
4. Use of big end up molds in place of the regular big end down type.
5. Insertion of chill plate assemblies in the bottom of a large ingot in order to break up the customary bottom cone structure.
6. Charging ingots upside down in soaking pits.
7. Close control on heating of ingots preparatory to rolling.

Some improvement was effected but in a tonnage mill there is always the difficulty that whereas the results of one experiment may appear satisfactory, it can be proven only by results on a number of heats on which practice is uniformly the same. Then, too, the occurrence of the woody fracture was such as to discourage correlation with items of practice. Both woody and crystalline fractures might be found on samples cut from:

1. Ingots of the same heat
2. Ingots of identical size cast simultaneously on the same bottom plate.
3. Different positions in the same plate (MBX the worst offender).

Some laboratory work was done on comparative samples of woody and of crystalline fracture steels to determine the cause of woody fracture. Spectrographic analyses of comparative samples were run to check on the presence of residual elements; no significant differences in composition were found. X-ray reflection pat-

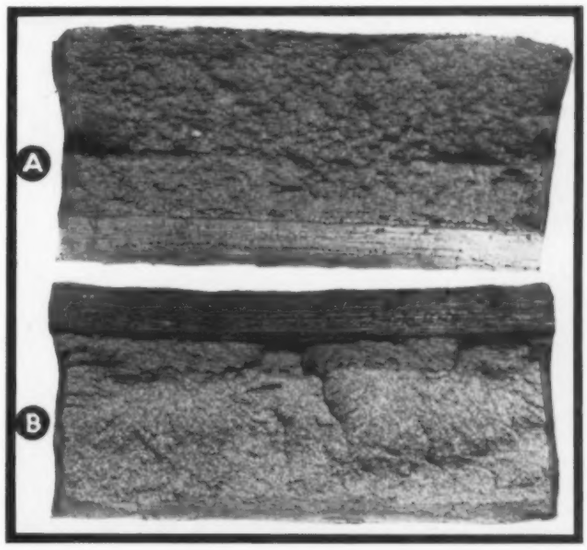


Figure 8—Sample C 5. *A*—Press Break. *B*—Hammer break.

terns taken with the beam striking the specimen surface at low angles (13 degrees and 16 degrees) failed to reveal any difference between comparative samples. Vacuum fusion analyses for gases indicated that the woody fracture sample contained approximately twice as much hydrogen and nitrogen as the crystalline sample.

Metallographic examinations usually failed to show any pertinent differences in structure or inclusions. Two inclusion investigations made by a supplier of ferro-alloys showed in one instance the presence of silicate slag fibers and in the other, the presence of alumina inclusions and sulfide stringers.

These experiments were not satisfactory because the individuals running the tests were seldom familiar with the whole background of the problem. No complete group of tests was run on a set of comparative samples. There was no follow-up of defective fractures with a macro-etch test. Relatively little metallographic work was done. Possibly most important of all, the variables involved in nick-break testing had not been investigated.

THE NICK-BREAK TEST

During the course of the investigation several hundred samples of different types of killed steels ranging in thickness from 3/16 in. to 5 in. were nicked and broken by different methods. The variables involved were studied to note their effect on the appearance of the resultant fractures. It was soon discovered that certain allowable changes in the method of breaking produced improved fractures, i.e., a leafy steel might become woody, a woody steel might exhibit a decreased area of woodiness, or a steel having a poor fracture might show a wholly granular break.

The specifications for the nick-break test, as given by the American Society for Testing Materials, were stated in the introductory section. The phrase, "broken with either a hammer or a press", alone allows a wide latitude in the appearance of the fracture. Samples were broken by the following methods:

1. Hydraulic press
2. Sledge hammer, and
3. Power hammer.

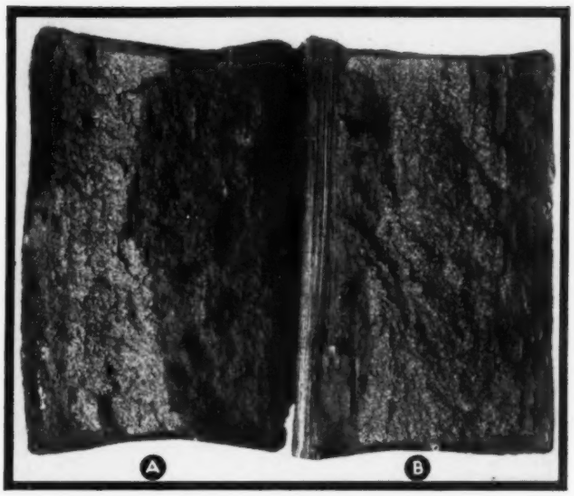


Figure 9—Sample G 15. *A*—Press break. *B*—Hammer break.

Figure 11 illustrates the positioning of the sample and the application of the breaking force for each of these different methods.

It can be definitely stated that the more rapid the application of the breaking force, the better the appearance of the fracture. Figures 6 to 10 inclusive are examples of improving the fracture by changing the method of breaking. In all of these cases the fractures are no further apart than 4 in. on the same sample. Sample D9, Figure 6, exhibited a stepped woody fracture when broken slowly in a press, a partially woody fracture (not shown) when broken more quickly in a press and a wholly granular fracture when broken under the power hammer. Sample F14, Figure 7, had a rough woody fracture with bad fissures when broken under

TABLE I

Heat Data

Heat	Ladle Analysis C	Mn	P	S	Si	Cu	Ni	Mo	Deoxidation practice
A	.20	.85	.021	.022	.23	.11	.10	.45	Silicon killed plus aluminum
B	.19	.93	.016	.021	.22	.10	.07	.42	Silicon killed
C	.18	.58	.017	.035	.24	.16	.08	...	Silicon killed plus aluminum
D	.26	.46	.015	.046	...	.31	.14	...	Aluminum killed in mould
E	.24	.51	.020	.034	...	.15	.10	...	Aluminum killed in mould
F	.25	.40	.013	.037	...	.16	.14	...	Aluminum killed in mould
G	.23	.51	.023	.038	.05	.15	.10	...	Semi-killed with aluminum and silicon
H	.27	.67	.021	.028	.21	.07	.06	...	Silicon killed
I	.11	.32	.015	.034	.12	.11	1.88	...	Silicon killed plus aluminum
J	.18	.40	.011	.035	...	.22	.09	...	Aluminum killed in mould
K	.19	.38	.015	.043	...	.21	.09	...	Aluminum killed in mould
L	.26	.71	.017	.040	.25	.22	.12	...	Silicon killed
M	.30	1.14	.015	.034	.28	.22	.15	...	Silicon killed

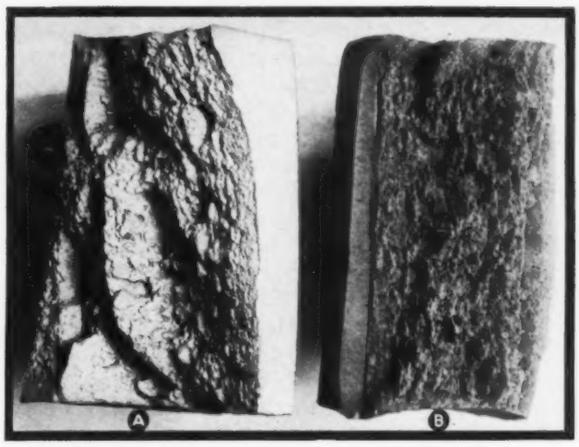


Figure 10—Sample H 16. *A*—Press break. *B*—Hammer break.

the hydraulic press whereas the power hammer break was wholly granular and satisfactory except for a few fissures. Sample C5, Figure 8, broken by the same three methods as D9 showed similar results with the exception that the hammer break was rough granular with some woody structure at the edges of the fracture face. In Figure 9, the woody area present in the press fracture of sample G15 is much larger than that in the hammer fracture. Notice, however, that the impact of the hammer blows has opened up larger fissures than can be seen on the press break. In Figure 10, the rough leafy fracture of the press break on sample H16 is compared with the rough woody fracture of the hammer break. Data on the various examples of fractures illustrated are summarized in Table 2. The instances cited are only a few of the many examples encountered which demonstrated that the impact method of breaking results in most cases in an improved fracture face.

Insofar as the variables in testing are concerned, the importance of sample thickness is second only to the method of breaking. The frequency of woody fracture was found to vary inversely with plate thickness. Woody fracture seldom occurred in samples over 1½ in. in thickness. The number of woody fractures increased with decreasing thickness to ¼ in. at which point most of the fractures exhibited a wholly woody condition. In the case of such light gauge plate, finishing temperatures may play in important part but metallographic samples of cross sections of ¼ in. and 3/16 in. plate exhibited a random orientation. The function of thickness might well be translated into terms of stiffness. Thus a thick sample may be so stiff that it resists deformation and ruptures with no noticeable deformation. A thin sample is so flexible that a marked amount of deformation takes place before rupture. The factor of degree of deformation versus the appearance of the fracture shows good correlation with the characteristics of rupture, the method of breaking and the stiffness (or thickness) of the sample.

The width of the sample is of little importance. Plate mill tests usually approximate 2 in. in width. Variations in width showed no effect on the characteristics of the fractures. The thickness is the dimension which plays the most important role.

The method of making the notch had no effect on the

Table II

Sample Data

Heat	Sample No.	Plate thickness, in.	Sample position	Type of fracture			
				Press break	Figure No.	Hammer break	Figure No.
A	1	1¾	MBX	Granular	12	.....	..
B	2	1¾	MBX	Woody	12	.....	..
C	3, 5	1	MTX	Woody	2 & 8	Granular	8 & 22
C	4, 6	1	MBX	Woody	2	Woody	22
D	7, 9	1⅝	MTX	Stepped woody	6	Granular	6 & 28
D	8, 10	1⅝	MBX	Very leafy	5	Very leafy	28
D	13	1⅝	MBX	Leafy center	4	Leafy center	4
E	11	1½	MBX	Granular	..	Granular	1 & 40
F	12	⅞	MBX	.....	..	Leafy	3
F	14	⅞	MBX	Cracked woody	7	Granular	7
G	15	1¼	MBX	Mostly woody	9	Less woody area	9
H	16	1	MBX	Rough leafy	10	Rough woody	10
I	17	½	T	.....	..	Leafy	35
I	18	½	B	.....	..	Leafy	35
J	19	½	MBX	Leafy	..	Leafy	37
K	20	½	MBX	Granular	..	Granular	37
L	21	1¼	MBX	Rough granular	39	Granular	..
M	22	3	MBX	Granular	..	Granular	41

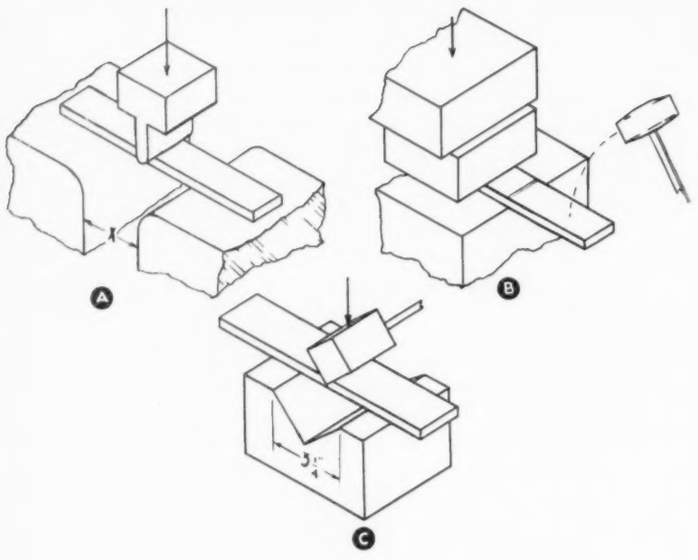


Figure 11—Different methods of fracturing samples. *A*—Press. *B*—Sledge. *C*—Hammer.

nature of the fracture in the samples studied. Notches at Lukens are made by a wedge mounted on the moving head of the hydraulic press. Notches were also milled and made by hand hacksaw (on light gauge samples) and by power hacksaw (on thicker samples). The chief purpose of the notch is to control the incipient point of rupture. The effect of the depth of notch is related directly to plate thickness in that increasing the depth of notch simply decreases the thickness of the sample to be broken. For thick samples the A. S. T. M. specifies a minimum depth of 2 in. for the face of the fracture. This allows examination of a large fracture area in the center of the plate where non-metallics are most likely to be segregated. If one were interested in determining susceptibility for woody fracture, it would probably be logical to specify a maximum depth of face of approximately 1 to 1¼ in. rather than a minimum depth of face of 2 in. No experimental breaks were made with notches at one place on both sides as recommended by the A. S. T. M. for thick plates.

The method of press breaking is illustrated by Figure 11A. The sample is supported at both ends, the notched face placed downward and the load applied on the unnotched face at the point opposite the notch. Two variables, the speed with which the load is applied and the length of the span, must be considered. Increasing the speed of application of the load results in an improved fracture. Length of span (designated by "X" in the sketch) is usually standardized and the maximum sample thickness that can be broken on a given span depends on the capacity of the press. Most of the work was done on a press having two spans, one of 9 in., the other, 15 in. Samples over 3 in. in thickness were broken on the latter. When samples under 1 in. in thickness were broken, a progressive decrease in span (down to 3 in. for a ¼ in. sample) improved the fracture. The natural flexibility of such thin samples usually resulted in a woody structure on a press break and the use of the sledge is therefore preferred on light gauges of plate.

The method of sledge breaking is illustrated by Figure 11B. One end of the sample is held firmly in the press with the notched face upward and the notch coinciding with the edge of the anvil. The free end of the sample is struck with a sledge. Many variables affect the quality of the fracture with this method of breaking. The less the number of blows required to break a sample of a given thickness, the better the quality of the fracture. Increasing the distance from the notch to the point where the blow is struck increases the leverage and gives an improved fracture. The heavier the sledge and the greater the strength and the skill of the person wielding it, the greater the improvement in the fracture. The breaking of samples by this method is limited by plate thickness, 1½ in. being about the maximum.

At the Timken company the only available press applied the load too slowly and there was no suitable equipment for holding a sample for a sledge break. Samples were therefore broken under a forge hammer actuated by compressed air. Figure 11C illustrates the

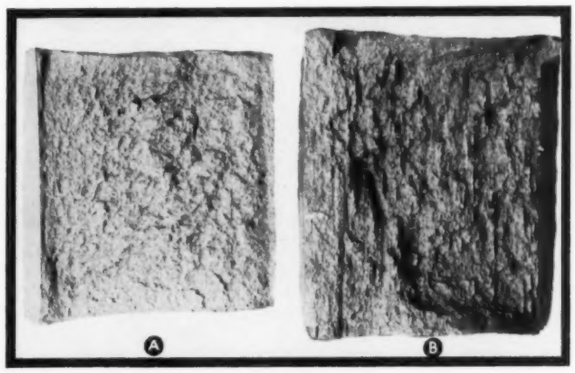
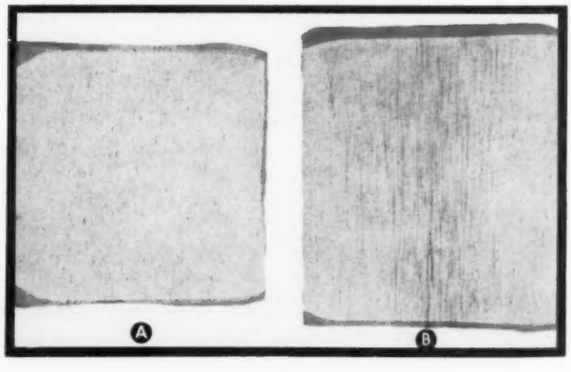


Figure 12—Fractures on set 1. *A*—Sample A 1. *B*—Sample B 2.

Figure 13—Macro-etches on set 1. *A*—Sample A 1. *B*—Sample B 2.



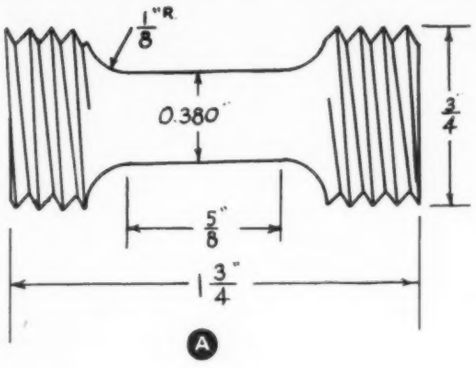
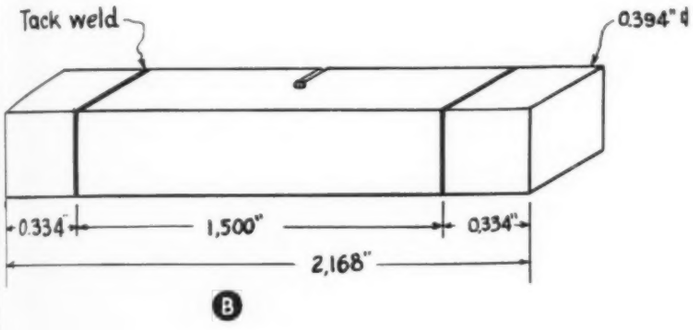


Figure 14—Special samples for physical testing. *A*—Miniature tensile specimen. *B*—Assembled Charpy impact sample.



method of supporting the sample on the lower V-block and applying the load through the upper V-block. The span used was a constant one of 3¼ in. although wider spans could readily be used for thick samples. The technique of fracturing, as practiced by a forger who had previous experience with the nick-break test in a tool steel plant, was uniform for each break. The sample was first placed notch upward across the V-block and a light blow was delivered that bent the test only slightly. The sample was then placed notch downward and given a light blow which straightened it. The fracture was then made with two heavier blows, the second sufficiently strong to complete the rupture. This method of breaking gave the most uniform and most satisfactory fractures of any of the various methods tried. The purpose of the preliminary deformation is apparently to work harden the metal, a procedure which doubtless increases the stiffness of the sample and enhances the possibility of securing a granular fracture.

Regardless of the method used in fracturing a sample, due care should be used in making the test. The notch should be made at right angles to the sides (sheared or gas-cut) of the sample. The notch should be of sufficient depth to insure the proper positioning of the rupture. Depth of notch should be uniform across the width of the sample. The notch should be properly centered between the supports (press or power hammer) or correctly aligned with the bottom support (sledge). The application of load should be as uniform as possible for samples of a given thickness. There should be a minimum of possible variables in the method of breaking.

The factor of temperature was not studied. Thum and Holdt[16] investigated this variable and reported that with increase in temperature, granular samples (at room temperature) became slaty whereas with decrease in temperature, slaty fractures (at room temperature) became granular. Thus, regardless of appearance of fractures made at room temperature, all samples broken at 212 F showed woody characteristics while the same samples broken at —76 F were all granular. Specimens were bent in a transverse testing machine with simultaneous measurement of both load and deflection. The rate of application of load was probably quite slow.

The nick-break test is an easy, convenient method of rupturing steel but the method of breaking must be standardized before any satisfactory interpretation can be placed upon the appearance of the fracture faces except in instances where pronounced segregations of non-metallics are shown.

COMPARATIVE SAMPLES

A majority of the investigational laboratory work was devoted to tests on three sets of comparative samples in an effort to determine causes (other than

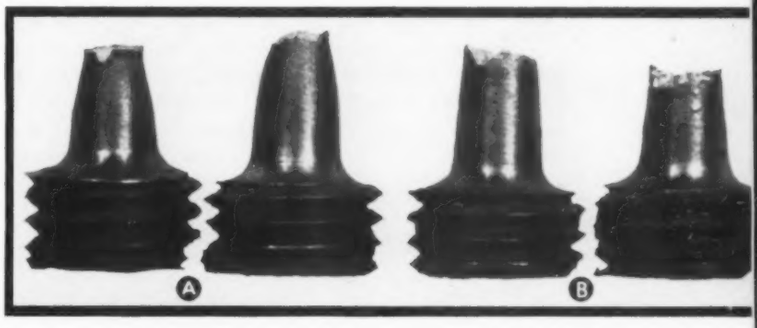
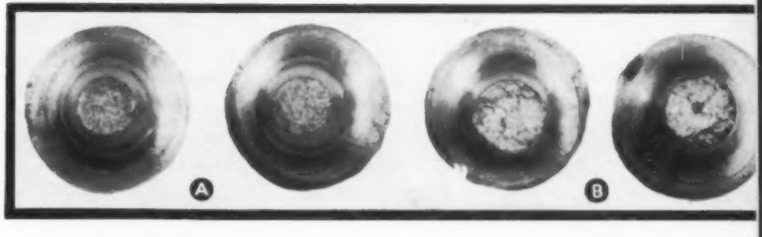


Figure 15—Broken miniature tensile specimens. *A*—Longitudinal. *B*—Through plate thickness.

Figure 16—Matching fracture faces of tensile samples. *A*—Londitudinal. *B*—Through plate thickness.



breaking method) for the occurrence of woody fracture. The samples are listed below.

Set 1. Sample A1 (Granular) vs. Sample B2 (Woody). MBX tests from two similar heats of silicon killed carbon-molybdenum steel.

Set 2. Samples C3, C5 (Granular) vs. Samples C4, C6 (Woody). Granular samples, MTX, and woody samples, MBX, from the same plate of a silicon killed heat.

Set 3. Samples D7, D9 (Granular) vs. Samples D8, D10 (Very leafy). Granular samples, MTX, and woody samples, MBX, from the same plate of a heat tapped and poured open and aluminum killed in the molds.

In the following discussion the results of testing on each set of comparative samples will be treated separately. The results of these various tests are listed in data tables (3 to 9 inclusive) in the appendix of this report.

Set 1—The fissures usually found in woody fractures indicated that major planes of weakness should parallel the rolled surfaces of plates exhibiting such fractures. To check this probability, physical tests through the plate thickness were required and this necessitated a set of comparative fractures in a plate thickness of approximately 2 in. As stated in the preceding section woody fractures are seldom found in plates over 1½ in. in thickness.

One set of satisfactorily comparative samples was found in plates of carbon-molybdenum steel 1¾ in. in thickness, namely, samples A1 and B2. On press breaks, A1 was wholly granular and A2, wholly woody. The fractures are shown in Figure 12. Only one sample, 18 in. x 2 in. x 1¾ in., was secured on each steel and any program of breaking was necessarily limited.

Slices for macro-etch tests were cut approximately ½ in. behind the fracture faces. The etching procedure used is that recommended in the *Metals Handbook*[21]. Samples were placed in a 1:1 solution of HCl for 30 minutes at 160-180 F. Etch tests are illustrated in Figure 13. The woody sample appears to be dirtier than the granular and certainly has greater segregations of non-metallics.

Ladle analyses of the two heats are given in Table 1 and check analyses on the samples are shown in Table 4A. The major difference is in manganese content. Practices shown on the heat logs differed on two items. On heat A, ½ lb of aluminum per ton was added in the ladle whereas none was added to heat B. Bottom trouble was encountered on heat B and a six hour delay for repairs followed the tapping of the heat. Plates in both instances were rolled from bottom-poured 48 in. x 21 in. ingots (hot-topped, big-end-down, slab type). Unfortunately no data are available on pouring or rolling temperatures.

Miniature tensile samples were cut through the plate thickness and in the longitudinal direction. Details of preliminary work on different sizes of miniature samples were given in the progress report. Dimensions of the samples used for the comparative tests are shown in Figure 14A. Eight tests were machined from each sample, four longitudinal and four through the plate thickness. Machined surfaces were polished with emery paper and punched for a ½ in. gauge length.

Difficulty was experienced in determining yield points on account of the short gauge lengths. The breaks on the longitudinal samples were well centered and were of the cup-cone type. Breaks on the samples taken through the plate thickness were not well centered and exhibited little ductility. The granular and the woody steels showed little difference on the characteristics of fracture in these tensile tests. Figures 15A and 16A illustrate matching halves of a typical longitudinal sample; Figures 15B and 16B illustrate a typical sample cut through the plate thickness. Note that in the latter case (Figure 15B) checks or ruptures occurred at points other than that at which the break took place. Data on tensile tests are given in Table 3A. Yield point data are fragmentary and definitely questionable. Granular samples in both cases (longitudinal and through the plate thickness) exhibited higher ultimate strength than did the woody. Note however, that the woody tests did not experience a sharp drop in "through the plate" strength as it had been predicted that they might. Ductility data are open to question on account of sample size. However, the woody samples exhibited more ductility (particularly in elongation which was more accurately measured than reduction of area) than did the granular samples.

Comparative Charpy impact strengths were also determined on samples cut in the longitudinal direction and through the plate thickness. The standard size of the Charpy keyed impact specimen is 2.168 in. x 0.394 in. square. Sample size was again limited by plate thickness and assembled samples were necessitated. Preliminary work on such tests was also described in detail in the progress report. The method of assembly consisted of tack welding pieces ⅜ in. in length to each end of a specimen 1½ in. long. During welding operations, the metal at the keyway was kept cool by a wet cloth. As soon as welding operations were completed, the samples were quenched in water to avoid any heat effect at the keyway. Excess weld metal was then filed off and tests were also filed to the proper length. Figure 11B illustrates the assembled impact sample.

Twelve tests were cut from each sample, six longitudinal and six through the plate thickness. Some of the samples were slightly off-size because of the filing involved in removing excess weld metal. This accounts for the spread in test results listed in Table 3B. Impact strength of longitudinal tests from the woody sample was far higher than that of the granular sample. Impact strengths of tests through the plate thickness was far lower than those cut in the longitudinal direction for both samples but the woody sample again exhibited better impact strength than did the granular sample.

The experiments with the miniature tensiles and the assembled Charpy impact samples indicate that in the case of the two samples under consideration, the strength of the "through the plate" tests are proportionately as good for the woody as for the granular samples.

Inclusions were electrolytically extracted from the samples by the modified Scott method described by Hare and Soler[22]. The separated inclusions were then analyzed by microchemical methods. Results of the analyses are listed in Table 4B. The relative amounts of the different oxides present check well with deoxidation practices. The total amount of non-metallics present in each of the two samples checked almost

exactly, a rather surprising point in that the samples came from two different heats.

Separated inclusion samples were examined under the petrographic microscope. Inclusions from A1 contained the following phases: alumina, medium to large amount; light yellow glass (R.I., 1.48), fair to medium amount and quartz, trace. Inclusions from sample B2 were generally colored a dark brown possibly due to the high manganese oxide content. Optical properties of all but the following were hidden: alumina, very small amount; colorless glass (R.I., 1.50), small amount and quartz, small amount.

Vacuum diffusion analyses were run to determine the occluded gas content of the samples. The method, briefly, consists of holding the steel sample in an evacuated tube at 1800 F and pumping off the gases liberated by the metal at this temperature. These gases are stored, measured and analyzed. Several tests were run on each sample. The spread and the average gas contents are shown in Table 4C. The spread between the

TABLE III

Comparative Samples—Set 1

A. *Miniature tensile tests*

Sample No.	Test	Yield point	Ultimate strength	Per cent reduction of area	Per cent elongation in ½ in.
A1 (Granular)	Longitudinal	.....	88,300	57	38
		.....	87,800	56	42
		78,300	87,000	60	44
		80,500	86,500	58	42
Averages		79,400	87,400	58	42
B2 (Woody)	Longitudinal	.....	83,500	59	50
		53,000	81,700	59	44
		53,600	81,600	63	52
		52,800	81,500	59	52
Averages		53,100	82,100	60	50
A1 (Granular)	Through plate thickness	.....	84,700	22	..
		.....	86,500	28	18
		.....	85,400	24	..
		73,900	85,100	27	22
Averages		73,900	85,400	25	20
B2 (Woody)	Through plate thickness	.....	80,200	24	24
		.....	80,600	22	18
		65,100	80,500	29	26
		63,500	78,900	18	22
Averages		64,300	80,000	23	25

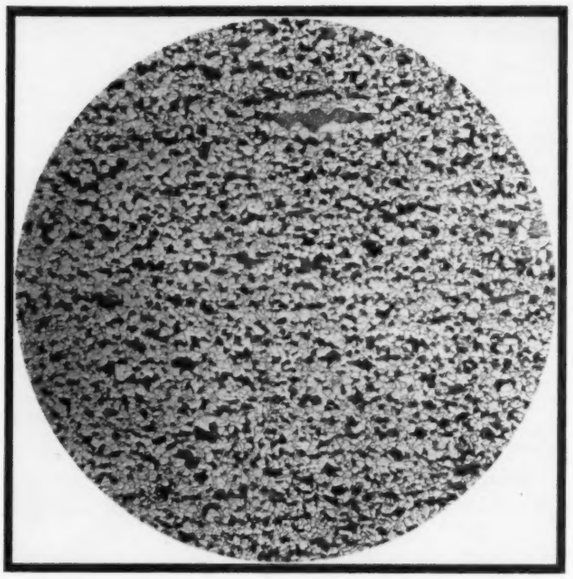
B. *Assembled Charpy impact tests*

Sample No.	Test	Impact strength in foot-pounds	
		Spread	Average
A1	Longitudinal	24–29	28
B2	Longitudinal	44–49	46
A1	Through plate thickness	10–14	13
B2	Through plate thickness	16–20	19

averages is far less than the spread between results on the individual samples. The averages show exactly the same gas content.

Major differences in metallographic specimens of samples in the as-rolled condition were found. Results are listed in Table 4A. The difference in cleanliness ratings are reflected in the results of the macro-etch tests. A pronounced difference in structural grain size was noted with the woody sample having a much finer grain than the granular sample. Microstructures (100x) of the samples A1 and B2 are shown in Figures 17 and 18 respectively.

Insufficient samples remained to test the effect of heat treatment on the nick-break results, but it was decided (on the basis of Charpy impact results) that heat treated impact tests should be representative of the type of fracture that might be expected. Samples were cut in the transverse direction for Izod impact tests. Some were broken in the as-rolled condition to check the Charpy results. A similar difference of impact values was found. Samples from both A1 and B2 were both normalized and annealed from 1750 F. Results of the Izod impact testing are shown in Table 5B. Heat treatment had little effect on the strength of the granular sample but both heat treatments dropped the impact strength of the woody sample down to values that approximated those of the granular sample. Microstructures of the woody sample (B2) resulting from the normalizing and the annealing treatments are



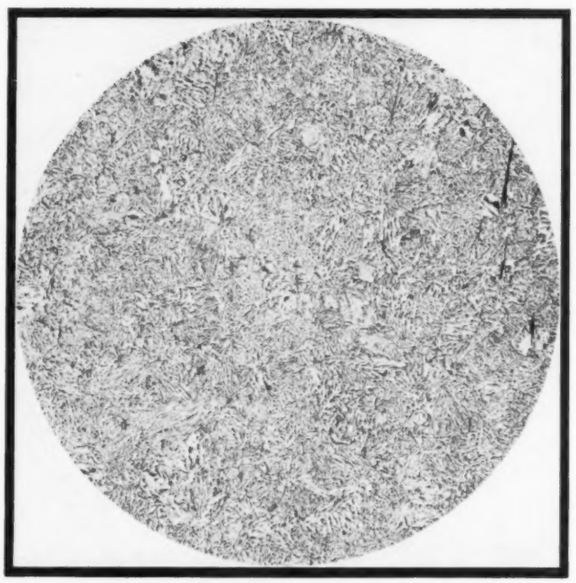
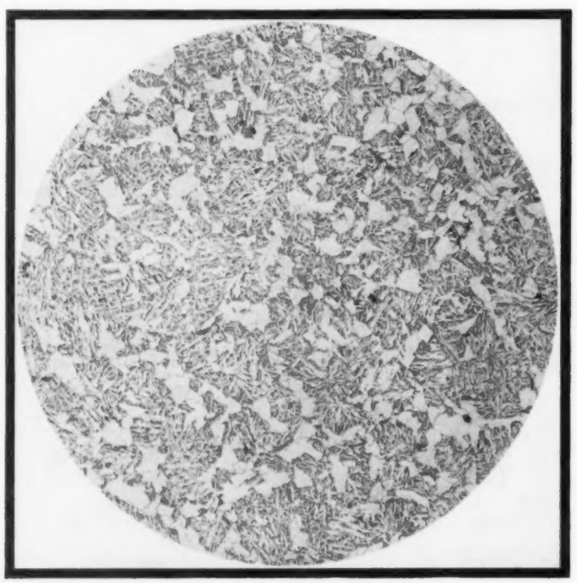


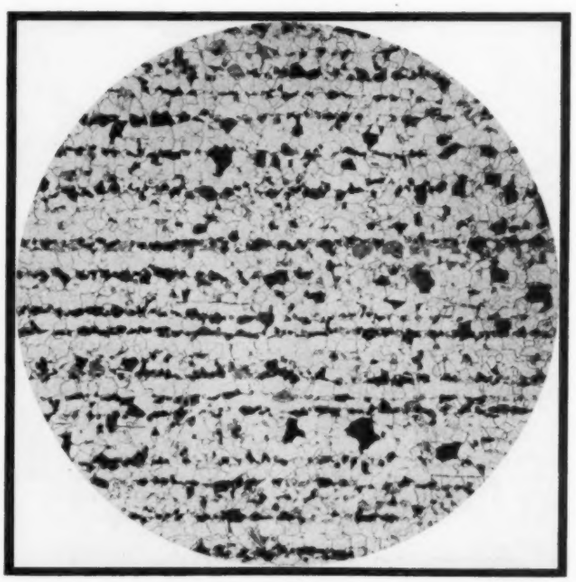
Figure 17—(Below) Sample A 1, as rolled. 100 x.

Figure 18—(Top right) Sample B 2, as rolled. 100 x.

Figure 19—(Center) Sample B 2, normalized 1750 F. 100 x.

Figure 20—(Below right) Sample B 2, annealed 1750 F. 100 x.





shown in Figures 19 and 20 respectively. Note that in the case of the normalized sample, the microstructure is similar to that of the granular sample. In the case of the annealed sample, the impact value is similar to that of the granular sample in spite of pronounced ferrite banding. The annealing treatment has greatly coarsened the grain. Figure 21 illustrates the nature of the impact fractures. Only one, sample 2B in the as-rolled condition, exhibits a wholly woody fracture. Fractures of heat treated tests are similar in exhibiting breaks having the same proportions of granular and of woody areas in the cases of both samples A1 and B2.

The testing program showed that the non-metallic and the gas contents of both samples were similar. Heat treatment of impact samples caused major changes in grain size, microstructure, impact strength and the nature of the fractures. Preliminary experiments indicated that no major planes of weakness lay parallel to the plate surfaces of the woody sample in spite of segregations of non-metallics. In this case the woody fracture was caused by a structural fine grain, due probably to a low finishing temperature on rolling operations.

The following two sets of comparative samples were furnished by Lukens at the request of the writer for the purpose of checking the results found on Set 1. The same comparative tests were used with the exception of the miniature tensiles and assembled Charpy impacts which were omitted.

Set 2—Samples cut from the top and the bottom of a plate of a silicon killed heat were received. The MTX tests (C3, 5) were wholly woody when broken slowly in a press, exhibited a mixed granular and woody fracture when broken rapidly in a press and had granular fracture (except for the sample edges) when broken under the power hammer. The MBX tests (C4, 6) exhibited a wholly woody fracture regardless of the method of breaking. Figure 22 illustrates the fractures resulting from the hammer breaks and shows the excellent contrast secured.

Slices for macro-etching were cut parallel to the

TABLE IV

Comparative Samples—Set 1

A. *Check chemical analysis*

Sample No.	Composition in per cent									
	C	Mn	P	S	Si	Cr	Ni	Cu	Mo	Al
A1 (Granular)	.21	.84	.016	.017	.22	.04	.09	.12	.44	.009
B2 (Woody)	.21	.93	.021	.020	.26	.03	.06	.12	.43	.010

B. *Inclusions—Microchemical analysis*

Sample No.	Composition in per cent				
	Al_2O_3	SiO_2	FeO	MnO	Total
A1	0.0059	0.0037	0.0032	0.0015	0.0143
B2	0.0018	0.0056	0.0024	0.0043	0.0141

C. *Occluded gases—Vacuum diffusion*

Sample No.	No. of determinations	Spread	Composition in per cent		
			H_2	CO	N_2
A1		Maximum	0.0021	0.0144	0.0008
		Minimum	0.0019	0.0118	0.0004
	3	Average	0.0020	0.0130	0.0006
B2		Maximum	0.0025	0.0177	0.0008
		Minimum	0.0018	0.0091	0.0002
	5	Average	0.0022	0.0129	0.0005

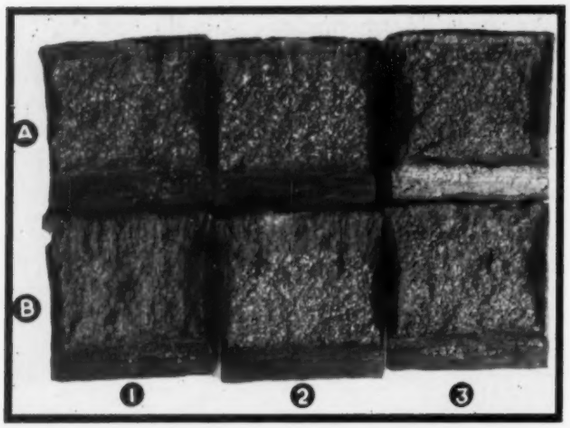


Figure 21—Izod impact fractures. A—Sample A 1. B—Sample B 2. 1—As rolled. 2—Normalized. 3—Annealed.

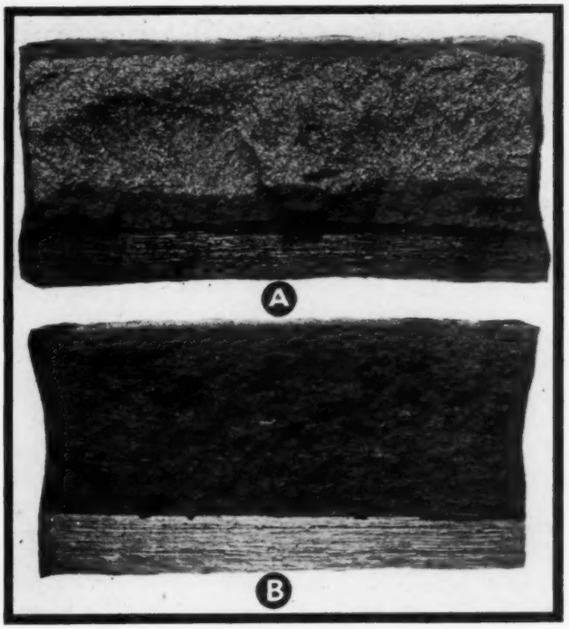


Figure 22—Fractures on set 2. A—Sample C 5 (MTX). B—Sample C 6 (MBX). *(Left)*

fracture faces. Figures 23 and 24 show respectively the etch tests on sample C5 (MTX) and C6 (MBX). Figure 25 illustrates similar tests on samples C3 (MTX) and C4 (MBX). Bottom tests in both cases were dirtier than top tests. Sample C5 contains more segregated non-metallics than sample C3 due possibly to being more nearly centered across the plate width.

Ladle analysis is given in Table I and check analyses on the samples are shown in Table 6A. Analyses of top and bottom samples are similar except for a positive segregation of carbon in the MTX test and a differential in aluminum contents. Analyses were also run for V, Mo, Ti, As and Sn but no significant differences were found. The heat was silicon killed and ½ lb of aluminum per ton was added in the ladle. A 48 in. x 21 in. bottom

TABLE V

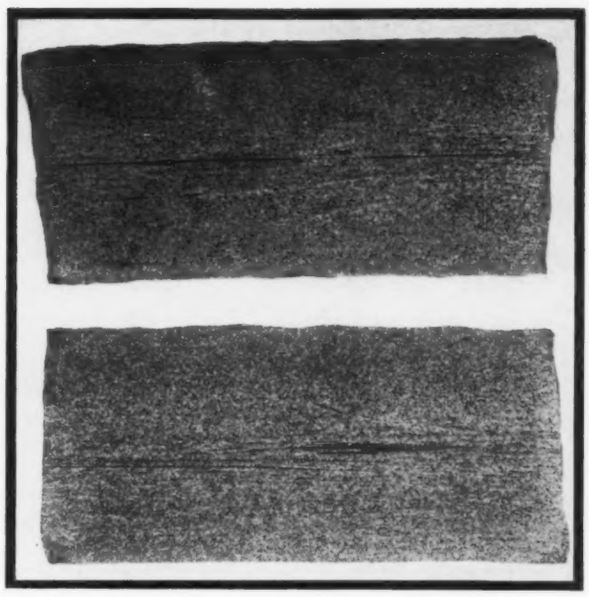
Comparative Samples—Set 1

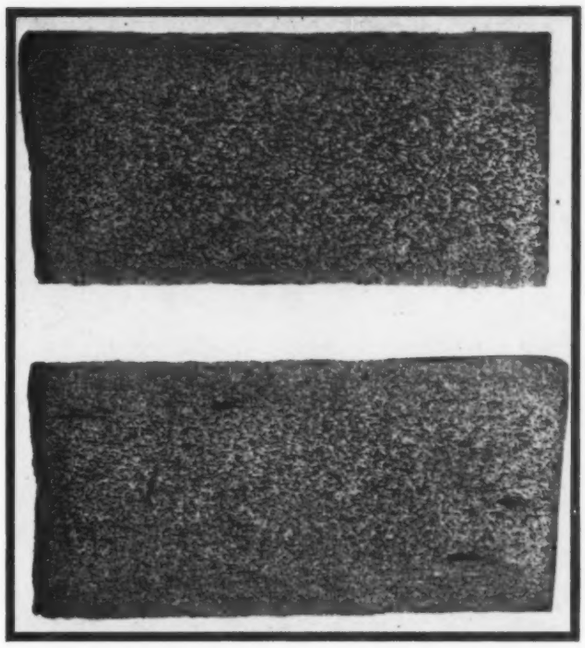
A. *Metallographic examination*

Sample No.	A1 (Granular)	B2 (Woody)
Cleanliness rating	Fairly good to fair: oxides and silicates	Poor: oxide stringers
Microstructure	Splined pearlite	Blocky pearlite and ferrite
Structural grain size	2/5	7/8
McQuaid-Ehn grain size	1/4	2/4

B. *Izod impact tests and Rockwell hardness readings*

Sample No.	Heat Treatment	Impact strength in foot-pounds		"Rb" hardness Average
		Spread	Average	
A1	As rolled	28–28	28	88
B2	As rolled	47–48	48	87
A1	Normalized—1750 F	20–29	25	94
B2	Normalized—1750 F	18–24	20	95
A1	Annealed—1750 F	25–27	26	79
B2	Annealed—1750 F	24–29	25	78





poured ingot was slabbed to 12 in., reheated and rolled to 1 in. plate. Pouring temperature was 2830 F; no information is available on rolling temperatures except that the breakdown of the ingot was made at 2250 F.

Results of microchemical analyses on separated inclusions are given in Table 6B. The bottom sample con-

Figure 23—(Left) Macro-etches on sample C 5.

Figure 24—(Above) Macro-etches on sample C 6.

TABLE VI

Comparative Samples—Set 2

A. *Check chemical analysis*

Sample No.	Composition in per cent								
	C	Mn	P	S	Si	Cr	Ni	Cu	Al
C3 (Granular)	.21	.58	.015	.033	.21	.06	.12	.18	.007
C4 (Woody)	.17	.56	.016	.030	.21	.06	.13	.17	.013

B. *Inclusions—Microchemical analysis*

Sample No.	Composition in per cent				
	Al_2O_3	SiO_2	FeO	MnO	Total
C3	0.0025	0.0042	0.0056	0.0007	0.0130
C4	0.0141	0.0072	0.0037	0.0025	0.0273

C. *Occluded gases—Vacuum diffusion*

Sample No.	Composition in per cent		
	H_2	CO	N_2
C3	0.0020	0.0160	0.0004
C4	0.0024	0.0232	0.0006

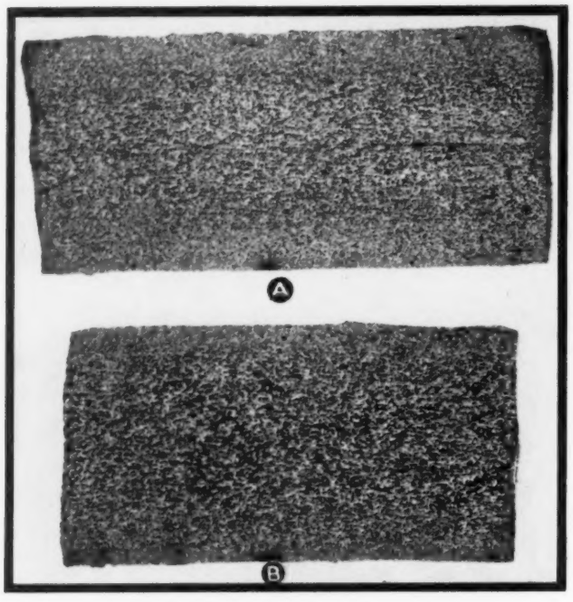


Figure 25—Macro-etches. *A*—Sample C 3. *B*—Sample C 4.

Figure 26—Sample C 4, non-metallics. 100 x.

tained over twice as much total non-metallics as did the top sample. Only FeO was present in greater quantity in the top sample.

Separated inclusions were examined under the petrographic microscope. Inclusions from sample C3 contained the following phases: colorless glass (probably high in Al_2O_3), medium amount; colorless glass, (probably high in SiO_2), fair amount; alumina, small to fair

TABLE VII

Comparative Samples—Set 2

A. *Metallographic Examination*

Sample No.	C3, 5 (Granular)	C4, 6 (Woody)
Cleanliness rating	Fairly good to fair	Poor: oxides and silicates
Microstructure	Ferrite and pearlite	Ferrite and pearlite
Structural grain size	4/8	4/8
McQuaid-Ehn grain size	1/4	4/7(1)

B. *Izod impact tests and Rockwell hardness readings*

Sample No.	Heat treatment	Impact strength in foot-pounds		"R_b" hardness Average
		Spread	Average	
C3, 5	As rolled	31–36	34	75
C4, 6	As rolled	42–45	43	72
C3, 5	Normalized—1750 F	42–46	44	79
C4, 6	Normalized—1750 F	48–52	50	72
C3, 5	Annealed—1750 F	34–35	34	69
C4, 6	Annealed—1750 F	41–42	42	64

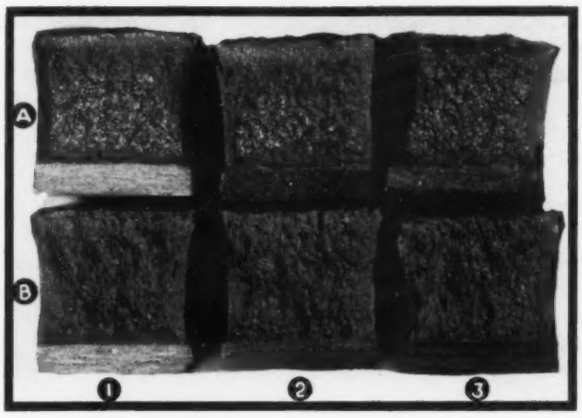


Figure 27—Izod impact fractures. *A*—Sample C 3. *B*—Sample C 4. *1*—As rolled. 2—Normalized. 3—Annealed.

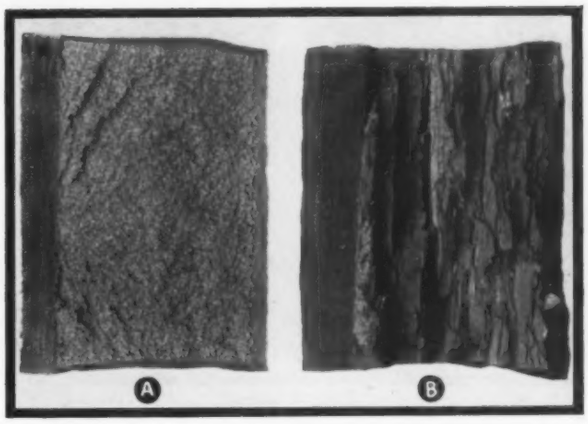


Figure 28—Fractures on set 3. *A*—Sample D 9 (MTX). *B*—Sample D 10 (MBX).

amount, and quartz, trace. Inclusions from sample C4 contained the following: colorless glass (probably high in Al_2O_3), fair amount; colorless glass (similar except for lower R.I.) fair to small amount; colorless glass (probably high in SiO_2), small amount; alumina, fair amount, and quartz, trace.

Results of vacuum diffusion analyses are listed in Table 6C. Some differences were found, with the woody

TABLE VIII

Comparative Samples—Set 3

A. *Check chemical analysis*

Sample No.	Composition in per cent								
	C	Mn	P	S	Si	Cr	Ni	Cu	Al
D7 (Granular)	.27	.45	.015	.037	.03	.10	.14	.36	.047
D8 (Very leafy)	.25	.44	.016	.036	.06	.10	.17	.35	.095

B. *Inclusions—Microchemical analysis*

Sample No.	Composition in per cent				
	Al_2O_3	SiO_2	FeO	MnO	Total
D9	0.0079	0.0014	0.0040	0.0001—	0.0134
D10	0.1518	Nil	0.0091	0.0001—	0.1610

C. *Occluded gases—Vacuum diffusion*

Sample No.	Composition in per cent		
	H_2	CO	N_2
D9	0.0022	0.0129	0.0006
D10	0.0037	0.0312	0.0009

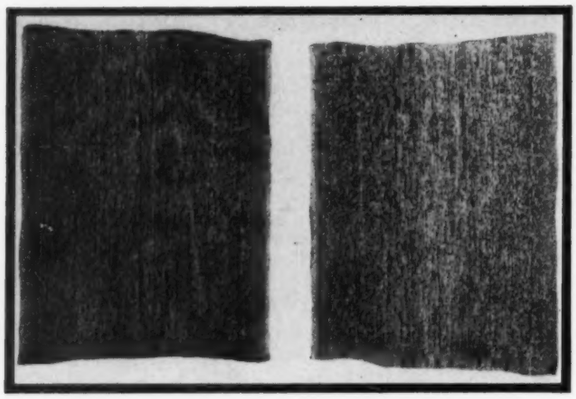


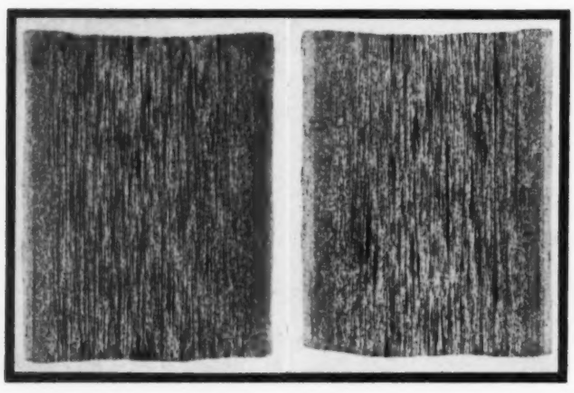
Figure 29—Macro-etches on sample D 9 (MTX).

fracture having a higher CO content. However, these differences are not of sufficient magnitude to be considered significant.

Metallographic examination revealed chiefly a difference in cleanliness ratings. Data are listed in Table 7A. The MTX samples were fairly clean but the MBX samples contained bad oxide (probably Al_2O_3) and silicate stringers. Figure 26 is a photomicrograph (100x) of an unetched sample (C4) and may be considered representative of the non-metallics present. No great differences were found in either microstructure or structural grain size. Inherent grain sizes were dissimilar due possibly to differences in aluminum content.

Blanks for Izod impact tests were cut and some were heat treated to determine if the samples would react similarly to those of Set 1. The results of impact testing and hardness determinations are given in Table 7B. In every instance the woody sample had higher impact strength than did the granular. Both samples reacted similarly to heat treatment. Tests in the as-rolled condition and annealed were similar in impact strength

Figure 30—Macro-etches on sample D 10 (MBX).



but the latter were lower in hardness. Normalizing increased the hardness and raised the impact strength of both samples. Fracture faces representative of the different conditions are illustrated in Figure 27. No granular structure was developed on the woody sample whereas the normalized granular sample was almost wholly woody.

Analyses of inclusions, macro-etch tests and cleanliness ratings on these samples all prove the woody (MBX) test to be much dirtier than the granular (MTX) test. Experiments with heat treated impact samples failed to reduce the strength of the woody sample to that of the granular. In this instance the factor

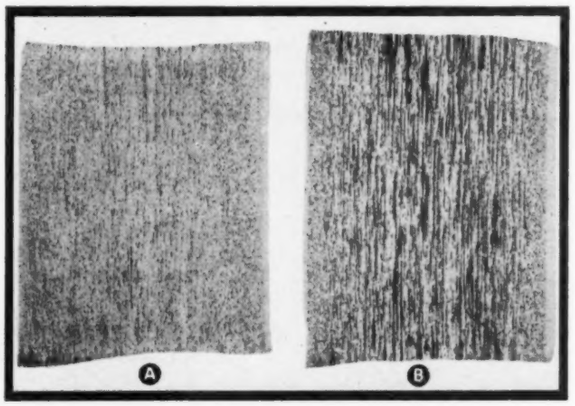


Figure 31—Macro-etches on set 3. *A*—Sample D 7 (MTX). *B*—Sample D 8 (MBX). *(Above)*

Figure 32—Sample D 8, non-metallics. 100 x.

controlling the nature of the fracture developed on the nick-break test is cleanliness.

Set 3—Samples of this set were taken from the top and the bottom of a plate rolled from a heat poured open and killed in the molds with aluminum. As in the

case of Set 2, the MTX tests (D7, 9) were wholly woody when broken slowly in a press, were mostly granular when broken more rapidly in a press, and had a wholly granular fracture when broken under the power hammer. The MBX tests (D8, 10) were extremely leafy regardless of the method used to break the samples. Fractures resulting from the hammer breaks are shown in Figure 28.

Slices for macro-etching were cut just behind and parallel to the fracture faces. Figures 29 and 30 show respectively the etch tests on sample D9 (MTX) and D10 (MBX). Figure 31 contrasts etch tests on samples D7 (MTX) and D8 (MBX). None of the MTX tests are of good quality and this probably accounts for the performance in the different methods of breaking. The MBX tests, extremely dirty, exhibited a bad segregation of non-metallics.

Ladle analysis is given in Table 1 and check analyses on the samples are listed in Table 8A. Sulphur in the samples is much lower than in the pit test; otherwise the check is fairly satisfactory. Note that the aluminum content of the MBX sample is twice that of the MTX test. Analyses were also made for other residual elements but no significant differences were found. Manganese was added in the furnace and ½ lb of aluminum per ton (to control rimming) was added in the ladle. The metal was bottom poured in 54 in. x 23 in. big end down, hot-topped molds. Approximately 1¼ lb of aluminum per ton was added in the center runner after the metal had reached the hot tops. Ingots were slabbed to 12 in., reheated and rolled to 1⅝ in. plate. No information is available on either pouring or rolling temperatures.

Results of microchemical analyses on separated inclusions are given in Table 8B. The bottom sample contained over ten times the amount of non-metallics present in the top sample. The chief offender was alumina, a fact which is not surprising when the method of deoxidation is considered.

Separated inclusions were examined under the petrographic microscope. Inclusions from sample D9 (MTX) contained the following: fine alumina, very large amount, colorless glass, small amount, and quartz, trace. Inclusions from D10 (MBX) contained: fine alumina, very large amount, colorless glass, very small amount, and quartz, small trace. The latter sample was composed almost entirely of fine alumina.

Results of vacuum diffusion analyses are given in Table 8C. Differences in gas content are indicated with the bottom sample containing more than the top. However, it is believed that the differences of non-metallic content outweigh in significance those found for the gases.

In the metallographic examination the samples showed a marked contrast in cleanliness, the top sample being the cleaner of the two. Data are listed in Table 9A. The MTX samples were only fairly clean but the bottom samples contained quantities of the oxide type inclusions, probably alumina. Figure 32 is a photomicrograph (100x) of an unetched sample (D8), representative of non-metallics present. No pertinent differences were found in either microstructure or grain size. Inherent grain size was fine on both samples.

Blanks for Izod impact samples were cut and heat treated as in the case of Sets 1 and 2. Results of impact tests and hardness determinations are shown in Table

TABLE IX

Comparative Samples—Set 3

A. *Metallographic examination*

Sample No.	D7, 9 (Granular)	D8, 10 (Very Leafy)
Cleanliness rating	Fairly good to fair	Poor: alumina
Microstructure	Pearlite and ferrite	Pearlite and ferrite
Structural grain size	4/8	6/8
McQuaid-Ehn grain size	7/8	7/8

B. *Izod impact tests and Rockwell hardness readings*

Sample No.	Heat treatment	Impact strength in foot-pounds		"R_b" hardness Average
		Spread	Average	
D7, 9	As rolled	15–17	16	77
D8, 10	As rolled	22–29	26	73
D7, 9	Normalized—1750 F	30–33	32	79
D8, 10	Normalized—1750 F	31–33	32	77
D7, 9	Annealed—1750 F	21–23	22	73
D8, 10	Annealed—1750 F	28	28	68

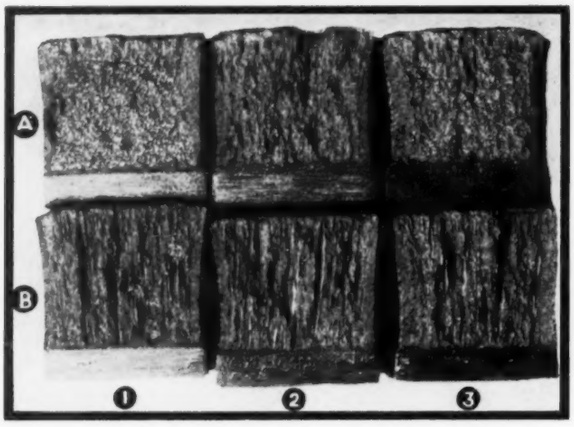


Figure 33—Izod impact fractures. *A*—Sample D 7. *B*—Sample D 8. *1*—As rolled. *2*—Normalized. *3*—Annealed.

9B. In both the as-rolled and the annealed states, the leafy sample exhibited higher impact strength than did the granular. In the normalized state, impact strengths were equal. Representative fracture faces are illustrated in Figure 33. Note that the granular sample exhibits a wholly woody impact rupture in the normalized condition. Pronounced fissures were developed on the impact ruptures of all MBX tests. One normalized bottom sample was notched at right angles to those shown in Figure 33 so that the break would be similar to those of the nick-break test. Impact strengths were 45, 49 and 51 foot-pounds. In no instance was the sample ruptured completely by the hammer. Figure 34 illustrates the fracture face and shows the extent of the fracture. The leafiness exhibited is similar to that found on the nick-break test. Heat treatment improved the impact strength of both samples. Normalizing raised and annealing lowered the hardness in comparison to that determined in the as-rolled condition.

Inclusion analysis, macro-etch tests and metallographic examination indicated that the leafy (MBX) tests contained more non-metallics than did the granular (MTX) tests. Experiments with heat treated impact samples gave results similar to those of Set 2 rather than of Set 1. Impact strengths were equal in the normalized condition but the granular tests in this instance exhibited wholly woody impact ruptures. As in the case of Set 2, difference in cleanliness is the factor controlling the nature of the fracture developed in the nick-break test.

Early plans called for a complete testing program to include an X-ray investigation, spectrographic analysis and possibly surface diffraction work on comparative samples. The issues regarding the cause of woody fracture were so confused that the many methods of testing were contemplated for an almost "blind search" for the cause. Some X-ray work was attempted at Lehigh University and exposures on comparative samples of Set 1 were made at a later date. However, the impact results on Set 1 and the macro-etch tests on Sets 2 and 3 were of such significance that plans for special tests (calling for equipment which was not available) were dropped. The inclusion studies, vacuum diffusion analyses and impact strength experiments were made to check the findings which were indicated by macro-etch testing and metallographic examination.

MISCELLANEOUS SAMPLES

Correlation of nick-break results and macro-etch testing, not only on comparative Sets 2 and 3 but also on other woody samples, was so encouraging that Lukens was asked to furnish a number of granular samples that might be etch tested. Most of these samples

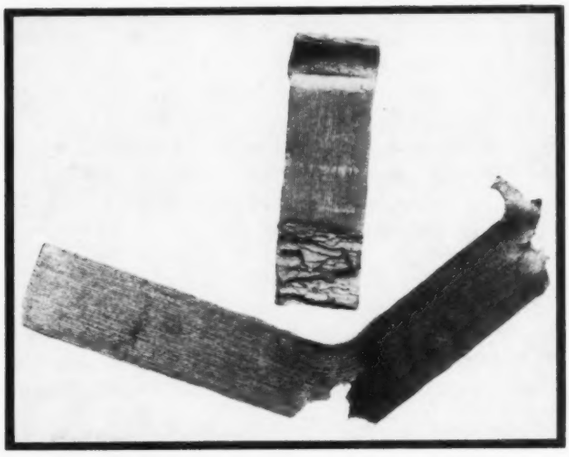


Figure 34—Sample D 8, leafy impact fracture.

were of heavier gauges (1½ in. and over). As has been stated in an earlier section, samples of this thickness usually break with a granular fracture, due probably to their stiffness which allows but little deformation before rupture. Many of the etch tests on these samples showed segregated non-metallics and others were fairly clean. There was little correlation between the nature of the fracture and the etch.

Figure 39 illustrates a rough granular fracture of a press break on sample L21. The hammer fracture on this sample was smooth granular (not shown). The etch test indicates a fair degree of non-metallic segregation.

Figure 40 illustrates hammer fractures and etch tests on sample E11. In this instance an attempt was made to correlate the fissure on break B with the etch test taken immediately behind the fracture. However, the etch test B showed no heavy non-metallic stringer whereas etch test A contained a bad stringer. Fracture A contained no fissures. The nick-break test in this instance cannot be considered as satisfactorily indicative of segregations of non-metallics.

Many samples of 3 in. to 6 in. in thickness were broken. All exhibited granular fractures and seldom

showed fissures. Figure 41 illustrates the fracture and etch test on sample M22. The sample was notched deeply on the gas cut face and broken under the hammer. When notched on the rolled face and broken under the press, the same type of fracture (including the rough areas and no fissures) was secured. The etch test contained a fair amount of non-metallic segregation.

Figure 7 illustrated a difference in fracture faces with different methods of breaking. Figure 38 shows the etch test on this sample. In spite of the extremely bad press break, no bad segregation of non-metallics is indicated.

Several hundred fractures were made with a sledge on light gauges of plate (⅜ in. to 3/16 in.). Most of the breaks were of the woody or leafy variety. Unfortunately this work was done at Lukens before the macro-etch testing was considered. Figure 37 illustrates fractures and etch tests on samples J19 and K20. Sample J19 had a very leafy fracture and the etch test contained bad segregations of non-metallics which could not be correlated with the fracture (insofar as position in the plate thickness is concerned). Sample K20 had a wholly granular fracture. (The fissure was developed when the fracture face was subjected to a light macro-etch as a cleanup before photographing). The etch test exhibits pronounced segregations of non-metallics.

During the last phases of the laboratory work, a shipment of eleven samples of ½ in. plate from two nickel heats were received. Ladle analysis of heat I, Table 1, is respresentative of the analyses. Samples were nick-break tested in the as-rolled and the normalized conditions. Breaks were made on both unbroken and broken tensile tests. All fractures were leafy and woody.

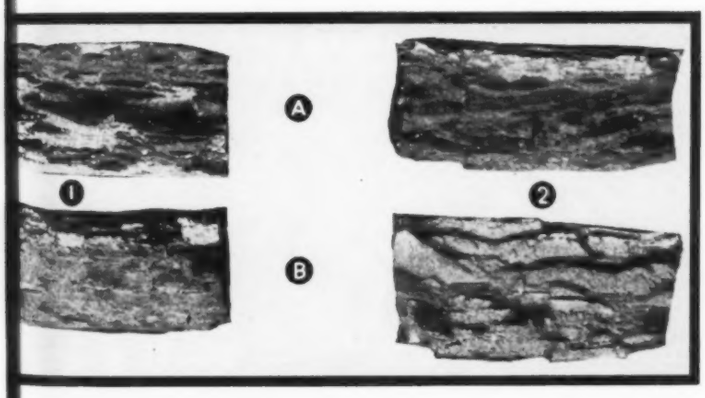


Figure 35—Hammer fractures. *A*—Sample I 17 (T). *B*—Sample I 18 (B). *1*—As rolled. *2*—Normalized.

Based on results reported at Lukens, it had been hoped that granular fractures could be developed by heat treatment. Figure 35 illustrates fractures on as-rolled and normalized samples from the top (I17) and bottom (I18) of one ingot. Figure 36 shows the etch tests on the samples. All contain stringers of non-metallics. A survey of heat data in the case of these two heats revealed high iron oxide contents in the finishing slags and high pouring temperatures, both of which should increase the probability of finding segregations of non-metallics in the finished steel.

The results reported above represent only a portion of the work done on nick-break testing and macro-etching. Correlation of these two test methods is none too satisfactory. The factors of breaking method and sample thickness often outweigh the important factor of cleanliness.

DISCUSSION

Experimental work with the nick-break test has shown that the thickness of the sample and the method of breaking are most important factors in determining the nature of the fracture. The effect of sample thickness may be interpreted as degree of resistance to deformation. Thus, samples:

(a) Below ½ in. in thickness were usually woody.

(b) From ½ in. to 1½ in. were critical in that they were most sensitive to methods of breaking and to the presence of non-metallics.

(c) Above 1½ in. in thickness were usually granular.

The method of breaking was governed to a great extent by the thickness of the sample, as follows. Samples:

(a) Below ½ in. were usually broken by sledge. Some experimental work on effect of span was done on the press with thin samples.

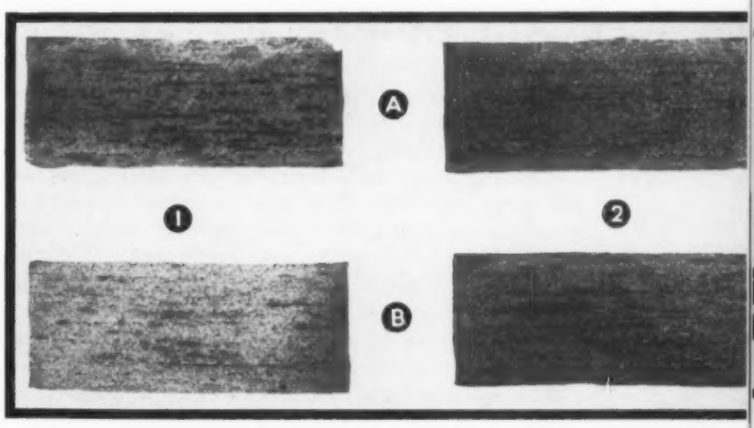
(b) From ½ in. to 1½ in. were broken by press, sledge and power hammer. Increase in speed of break usually resulted in an improved fracture. The power hammer is preferred over the sledge because its action is more positive and because it can be better controlled.

(c) Over 1½ in. were broken by press or by power hammer. If press-broken samples of this thickness exhibit a leafy fracture, hammer breaks on the same samples usually produce improved fractures.

This work indicates that samples in an approximate thickness range from ½ in. to 1½ in. may be defined as critical and that it is in this range that the method of breaking is a controlling factor.

The degree of cleanliness affects the quality of the fracture and, in the critical thickness range, will often

Figure 36—Macro-etches. *A*—Sample I 17. *B*—Sample I 18. *1*—As rolled. *2*—Normalized.



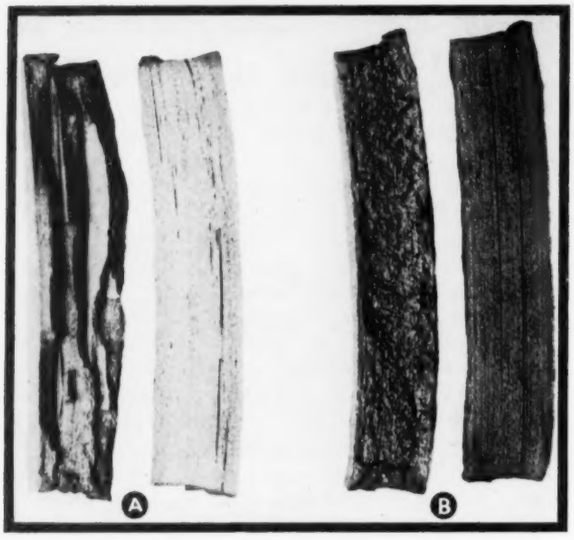


Figure 37—Fractures and macro-etches. *A*—Sample J 19. *B*—Sample K 20.

be responsible for the different fractures found with different methods of breaking. However, insofar as woody fracture is concerned, samples:

(a) Under ½ in. may be woody even if they are quite clean.

(b) From ½ in. to 1½ in. may vary in the nature of the fracture due both to method of breaking and to non-metallics.

(c) Over 1½ in. are usually granular. The presence of non-metallics or unwelded blowholes may result in fissures which may or may not be surrounded by localized woody areas. The presence of large amounts of non-metallics gives a fibering which increases toughness and usually causes a leafy fracture.

Any non-metallics are usually oriented and in most cases elongated by rolling to give some fiber effect. This increases toughness, gives the steel an ability to deform before rupture and may result in either a woody or a leafy fracture depending on the degree of fiber present.

In at least one instance, a fine structural grain size was found to be the cause of woody fracture. Factors influencing structural grain size include deoxidation practice as reflected by inherent grain size, finish rolling temperature and cooling rate from this temperature. Again the factor of plate thickness is important in that the cooling rate is much slower for a thick plate than for one of light gauge.

Even if the method of breaking were to be standardized, the effect of the other variables must be taken into account in interpreting the results of the nick-break test. Samples which give a leafy break under the hammer may be considered defective due to non-metallic fibers. Samples exhibiting either granular or woody fractures may or may not be satisfactory insofar as cleanliness is concerned. Some further inspection, such as macro-etch or metallographic examination, should be used, particularly when the quality of a plate is questioned.

The characteristics of both granular and woody fractures have been described. In press breaking, the load is usually applied slowly and the action of the metal under stress can be easily observed. Granular fractures are produced when rupture occurs before noticeable deformation takes place. Woody (and leafy) fractures are produced when rupture occurs only after a very noticeable deformation of the test piece. The former exhibits characteristics of brittleness; the latter, toughness. The metallic appearance of the granular fracture and the gray coloring and roughness of the woody fracture must then be related to the mechanics of rupture. An investigation of this point is beyond scope of the present problem. The findings of other workers may be used to explain the difference in the appearances of the granular and the woody fractures.

Taylor and Elam[23] reported that in the distortion of

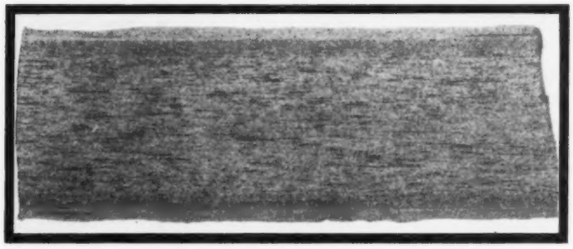


Figure 38—Macro-etch: Sample F 14. (Fractures shown in Figure 7).

iron crystals, deformation occurs along certain crystallographic directions rather than along crystallographic planes. In the present instance granular fractures may take place along cleavage planes whereas woody fractures may be governed by deformation and may occur along the crystallographic direction in which slip is taking place.

Extensive work has been done on factors involved in notched bar or impact testing. This material is reviewed briefly in the Metals Handbook[24] and is covered in detail in Hoyt's work[25]. Moser[26] experimented with width of sample and found that impact strength dropped sharply after a given width of sample was attained for a given steel. In other words, when sufficient stiffness of sample was attained, the characteristic of the fracture changed from tough (fibrous or woody) to brittle (granular). The Ludwik theory of notch effect (discussed by Hoyt) states that brittle (i.e., granular) failure of ductile steel occurs when the cohesive strength of the material is exceeded before deformation sets in.

Sauveur[27] (and others) in discussing grain growth show that at any temperature below that at which grain growth occurs, the cohesive strength of the crystalline phase is less than that of the amorphous phase (grain boundaries). Thus, at room temperature, if the cohesive strength is exceeded before deformation sets in, the rupture should occur through the crystalline phase along cleavage planes.

Recent X-ray work by Goss[28] indicates that plastic

deformation does not distort the space lattice of alpha iron but fragments the grains into much smaller particles. This substantiates Jeffries and Archer's[29] theories on plastic deformation and the hardening of metals by cold working. One might then speculate that in the present instance the appearance of a fracture may be governed by particle size at the moment of rupture, i.e., relatively coarse for the granular fracture and extremely fine for the woody fracture.

Figure 42 shows an interesting fracture encountered early in the experimental work. The heat is not identified but the etch indicates that it was aluminum killed in the mold. The face of the fracture was etched to clean it up for the picture. The sample was notched on the gas cut edge rather than on the rolled face. The load was applied on the edge at a point opposite the notch. The sample was sufficiently stiff to give a granular fracture during the first half of the rupture. Meanwhile the upper portion was undergoing deformation in compression. As the rupture progressed into the upper portions, the fracture became woody and exhibited more fissures than did the granular portions. These fissures were probably opened during compressive deformation. The effect of the fibers of non-metallics is somewhat different than that shown when samples are notched on the rolled face.

The preceding points may now be combined to explain the difference between the granular and the woody types of fracture. Granular fracture occurs when the cohesive strength of the crystalline phase is exceeded before deformation sets in. The rupture takes place along cleavage planes. Particle size is large because no fragmentation due to cold working precedes the rupture. Woody fracture occurs when a great amount of deformation takes place before the cohesive strength is exceeded. Due to the fragmentation during deformation, the particle size is fine. The rupture takes place along slip planes or more properly, directions of slip.

Little has been said concerning variables of steel making practice and their effect on the quality of the fracture. It has been found that non-metallics play a part in determining the nature of the fracture. If the non-metallics can be identified, the problem becomes one for the steel mill metallurgist to solve by reviewing the practices in his individual plant. All samples used in the present investigation were furnished by the Lukens Steel Company and the following discussion pertains chiefly to their practices.

Material Charged. Due to the location of the plant, a major portion of the material charged may be miscellaneous scrap gathered from Eastern markets. Much of this scrap is rusty at the time of charge. If woody fractures were attributable to rusty scrap, a majority of the samples broken would have exhibited such fractures.

Furnace Practice. Basic steel may contain inclusions originating from refractory hearth materials but in all the inclusion studies made by the Timken Roller Bearing Company, no such inclusions have been encountered. Factors such as bath temperature, condition of the bath at block, and deoxidation practice all affect the cleanliness of the steel produced.

Teeming Practice. Practically all the heats at Lukens are bottom poured in big end down, slab-type molds. Woody fractures occur most frequently on MBX samples and are attributed to a bottom-cone condition. Inclusion studies have shown that the MBX tests contain more non-metallics than the MTX tests from the same plate. Geiger, in discussing a paper[30] on solidification of steel, states that a cone condition may be caused by precipitation of pure crystals from the molten center of the ingot after the major cooling effect

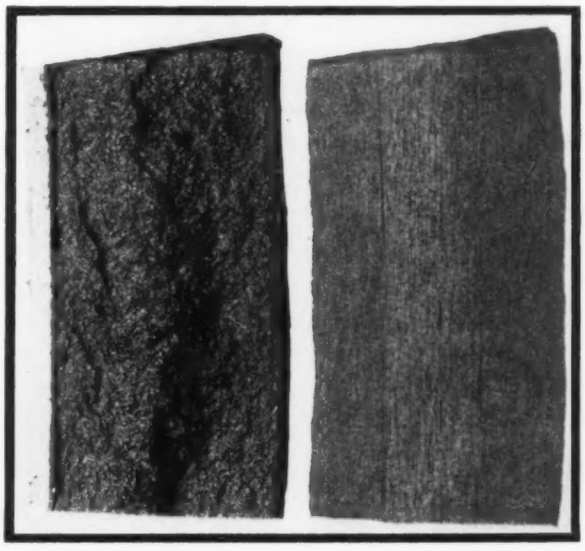


Figure 39—Sample L 21. Press fracture and macro-etch

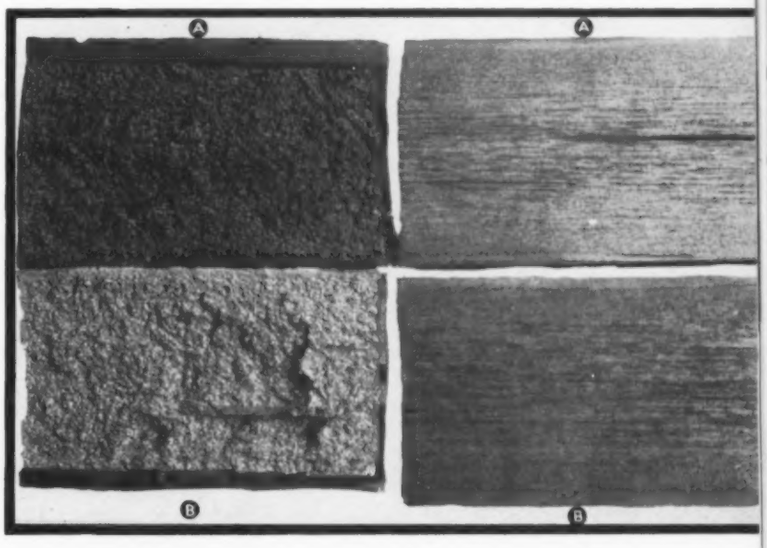


Figure 40—Hammer fractures and macro-etches on sample E 11. Etch "A" cut just behind fracture "A". Etch "B" cut just behind fracture "B".

of mold chill is spent. Refractory inclusions, solid at the temperature of the molten metal, act as nuclei for the formation of these crystals. This precipitation of iron crystals from the melt accounts not only for negative segregation of carbon in ingot bottoms but also for the concentration of non-metallics at this point. Hare and Soler[31] have presented a diagram showing cleanliness ratings on the cross section of a typical ingot. Their drawing shows a bottom cone rated poor in cleanliness in a big end up, top-poured ingot. When teeming is completed in bottom pouring, the metal at the bottom of the ingot is comparatively much hotter than at the top of the ingot. This should enhance the possibility of segregation of non-metallics as should high pouring temperatures.

Deoxidation in the Molds. Macro-etch tests and inclusion analyses have proven that steel deoxidized in the mold with aluminum contains a large amount of alumina. If cleanliness is desired, this practice cannot be considered acceptable.

Hot Working. In rolling, the non-metallics present

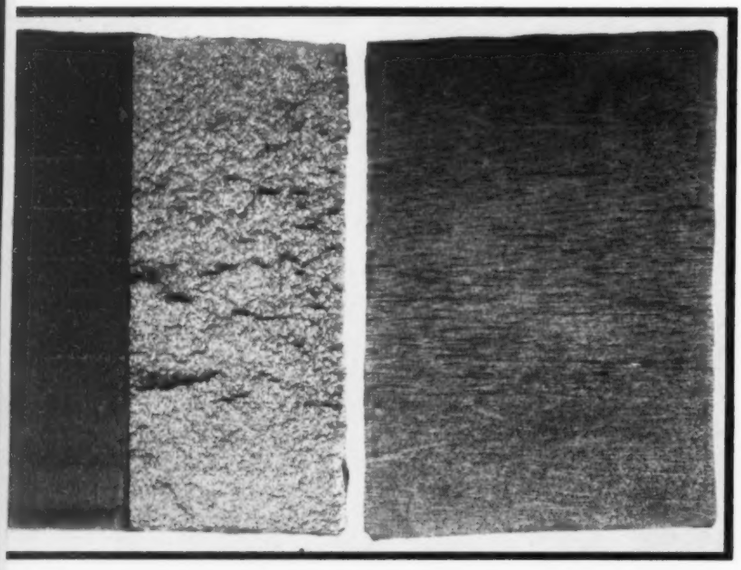


Figure 41—Fracture and macro-etch on sample M 22.

Figure 42—Fracture of sample nicked and broken on edge rather than on rolled face.

are forced closer together in the direction of force application and elongated in the direction of rolling. This results in a fiber which may cause either woody or leafy fractures depending on the amount of non-metallics and the severity of the fiber. The effect of finishing temperature and plate thickness upon structural grain size have been discussed above.

Little can be stated regarding the significance of woody fracture in relation to steel quality. Either a woody or a leafy fracture is indicative of toughness. The woody fracture may or may not be associated with an undesirable amount of non-metallics. Leafy fracture is usually caused by a bad degree of non-metallic segregation. The writer has interpreted the term "woody" as defining a ductile break characterized by the dull gray color of the fracture face; this appearance is believed to be related to the mechanics of rupture.

The evaluation of plate quality by use of the nick-break test requires careful consideration of all factors involved. In the case of thick plates or of a power hammer break, a granular fracture may not be indicative of a satisfactorily clean steel. Woody fracture on a plate of intermediate thickness broken under a press certainly may not be indicative of dirty steel. If there is any question as to quality of a plate because of woody fracture, further testing should be done. A macro-etch test or a metallographic examination for cleanliness should be used if a satisfactory non-metallic rating is desired.

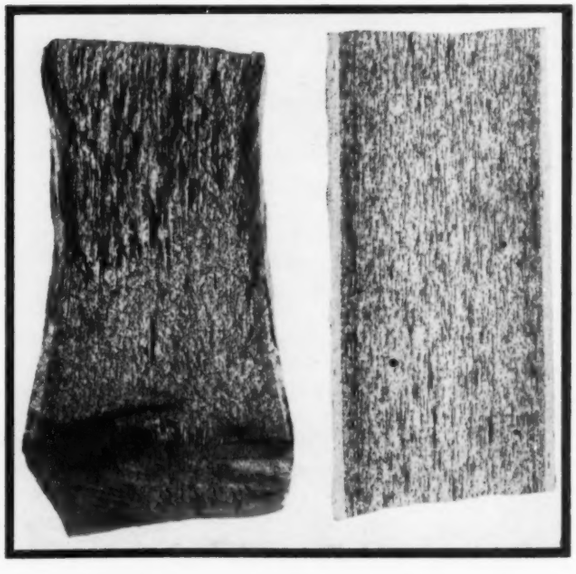
The nick-break test is advantageous for the plate industry because a minimum amount of sample preparation is necessary. Breaks may be made on tests as cut from the plate or on tensile samples (broken or unbroken). In the case of rimmed or of semi-killed steels, unwelded blowholes may be revealed if a sufficient number of breaks are made. In the case of killed steels, the break may be poor if the steel is excessively dirty. Steel exhibiting a granular break may be quite dirty. On the basis of the work involved in this investigation, the writer does not believe the nick-break test is a satisfactory method of determining steel quality.

SUMMARY

Experiments with the factors involved in making the nick-break test have shown that the nature of the resultant fracture may vary with the plate thickness and with the rate of application of the load.

If the use of the nick-break test is to be continued, equipment and procedure for the breaking of the sample should be standardized.

If susceptibility to woody fracture is to be determined, plate thickness should be limited by a deep



notch and a maximum width of fracture face rather than a minimum width should be specified.

In addition to method of breaking, both structural grain size and non-metallics have been found to be causes of woody fracture.

The factor of cleanliness is important in determining the nature of the fracture but the results of the nick-break test alone cannot be considered as a satisfactory index of steel quality.

The contrast in appearances of granular and of woody fractures may be explained by mechanics of rupture. Granular fractures result when the cohesive strength of the crystalline phase is exceeded before deformation sets in and rupture occurs along cleavage planes. Woody fracture occurs only after pronounced deformation takes place and the rupture occurs along slip planes (or directions of slip). Particle size at the time of rupture may also be a factor in determining the appearance of the fracture face.

Samples examined have been limited to the product of one plant. The "bottom cone" condition is probably a cause of poor quality on MBX tests but the same condition has been indicated by cleanliness ratings on ingots produced by pouring pit practices which are the opposite of those used in the production of slab-type ingots destined for plate.

Aluminum killing of steel in the molds results in unsatisfactory quality from the standpoint of cleanliness.

Finish rolling temperature and probably plate thickness affect structural grain size. A fine structural grain may cause woody fracture.

The significance of the different fractures produced by the nick-break test is questionable. It is recommended that this method of testing be supplemented by other tests such as macro-etching or metallographic examination, particularly if the application is one where cleanliness may be a factor.

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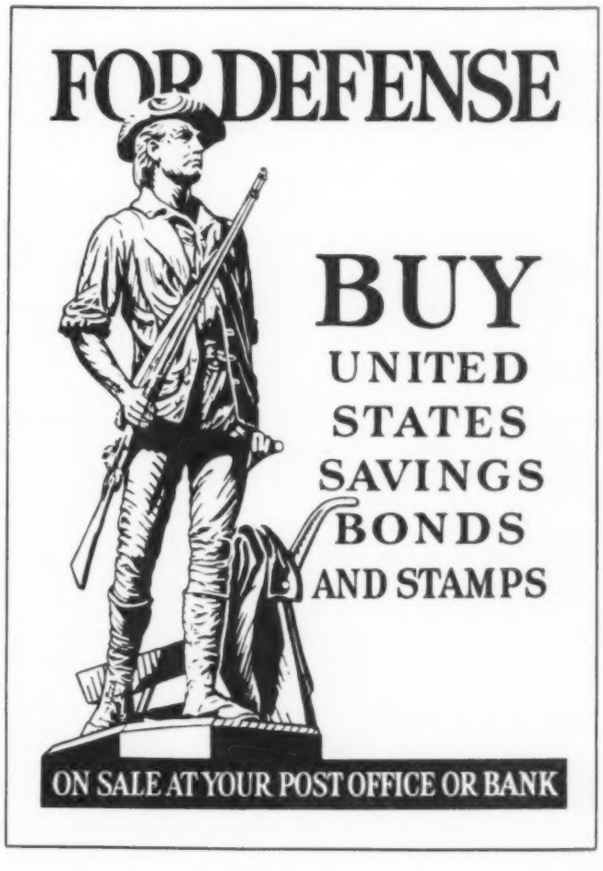

FUEL APPLICATION *in*

Metallurgical Heating Furnaces

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Presented at A. I. S. E. Annual Convention, Cleveland, Ohio

▲ THE application of fuel in metallurgical heating furnaces dates back many years to the time when furnaces were a pile of stone and wood was used for the fuel. Since then, many steps have been taken to find a means for obtaining desired results in our heating cycles. The burning of fuel has never been a very exact science. Perhaps in the last fifteen years more improvement has been made in the design of furnaces and the quality of the product heated than has been made in the one-hundred year period previous to that time.

It may be unwise to consider the application of fuel a very exact science today. Practically all our modern furnaces have been gradual developments of furnaces that have been inherited from previous generations. Fuel application has been very much a hit-or-miss proposition with very few sound facts to work upon.

We have all seen furnace designs duplicated and furnaces rebuilt over supposedly the exact dimensions and still the results from these two duplicate furnaces were not comparable. One would heat properly while the other always gave trouble. There must certainly be definite reasons why one furnace heats and the other does not. One of our main problems is to find out the reasons why one job will work while the other will not.

If we could satisfactorily calculate all the various factors that go into furnace operation, we would eliminate many of the headaches which confront not only furnace designers and burner manufacturers, but the operators as well.

Not many years ago the boss bricklayer in our steel plants had more to say about the design of our heating furnaces than did any other individual. Very often the bricklayers would continuously change various sections until they finally arrive at a furnace which gave fair operating results. At least it would heat steel with a minimum of trouble. After that furnace was once built, no one had a complete record of its design. The next time it was rebuilt it would be almost impossible to have it duplicated.

At other times, burners were changed in design, size, and type of manufacture and eventually a working furnace was developed.

If we are to progress in the application of fuel, we should determine why a heating furnace does not work and why a change in burners or furnace design does work. If we can determine the answers for the successful solution of a furnace design, then we can obtain known factors upon which to base calculations for better and more extensive design.

Thirty years ago the heater was a god in his own domain, and perhaps rightly so. He did not know how much air was required to burn the fuel; and if he had known, he was furnished with no means of telling how much was used. However, he did know, after years of experience, how to get the most out of the equipment he had to operate. He could open a door, adjust a damper, or turn on more fuel or air, and get a pretty fair result. In many cases, the old heaters have been criticised by our operators and combustion engineers as not taking care of his job properly. It has often been said that if the heater would take care of his job, he could save a lot of fuel. In perhaps a few instances this has been true, but in the great majority of cases furnace design has been such that the heaters could do little about correcting the existing conditions. We have all seen cases where the heater changed the flow of fuel to a furnace without giving any thought to the flow of air. Did you ever stop to think that perhaps the heater was forced to operate by this method, and that the furnace design was such that if the heater turned on the proper amount of air for combustion, the furnace got too hot in the wrong spot?

HEAT ABSORPTION OF STEEL

To analyze a furnace problem, we should understand the possible rate at which steel can absorb heat. We will make no attempt to arrive by a theoretical calculation at a set of values for heat transfer from flame to steel. Too many variables and assumptions exist by this method to be considered in a discussion of this character, but some experiments have been made in a batch furnace in which pieces of steel were heated and which give us a fair picture as a start. Figure 1 shows the temperatures on the surface and in the center of a series of billets heated in a batch furnace under the following conditions:

1. Furnace temperature was maintained constant and set at final steel temperature.
2. Outside steel temperature was measured by thermocouples attached to steel surfaces.
3. Center steel temperature was obtained by drilling a hole into the center of the piece and inserting thermocouples for temperature measurement.

4. All tests were made with pieces resting on solid furnace hearth and exposed to furnace temperature from all sides.

Figure 1 shows the results of these measurements and indicates that some of our ideas should be changed. The outstanding factors that are indicated in these tests are:

1. If the surface of the steel is up to temperature, the inside of the steel is very close to that temperature providing the temperature differential between flame and steel is not too large when the steel surface is hot.
2. Heating rates at a constant temperature are greater than normally expected.
   a. 6 in. square billets heated from two sides in 45 minutes or from one side in 90 minutes. This gives possible heating rate of 160 psf of steel surface per hour for one side heating.
   b. The curves show:
      10 in. squares heated in 100 minutes,
      13 in. rounds heated in 140 minutes,
      20 in. rounds heated in 200 minutes,
      or roughly ten minutes per inch of thickness for two-side heating.
3. The maximum temperature difference between inside and outside of steel billets in a constant temperature furnace is
   a. 6 in. square—100 F
   b. 10 in. square—200 F
   c. 13 in. round—200 F
   d. 20 in. round—600 F
4. For small billets and slabs, 4 in. or under, the temperature difference can be practically neglected, for if the surface is hot the center is not far away. As we will discuss later, this has a marked effect on some of our furnace designs.

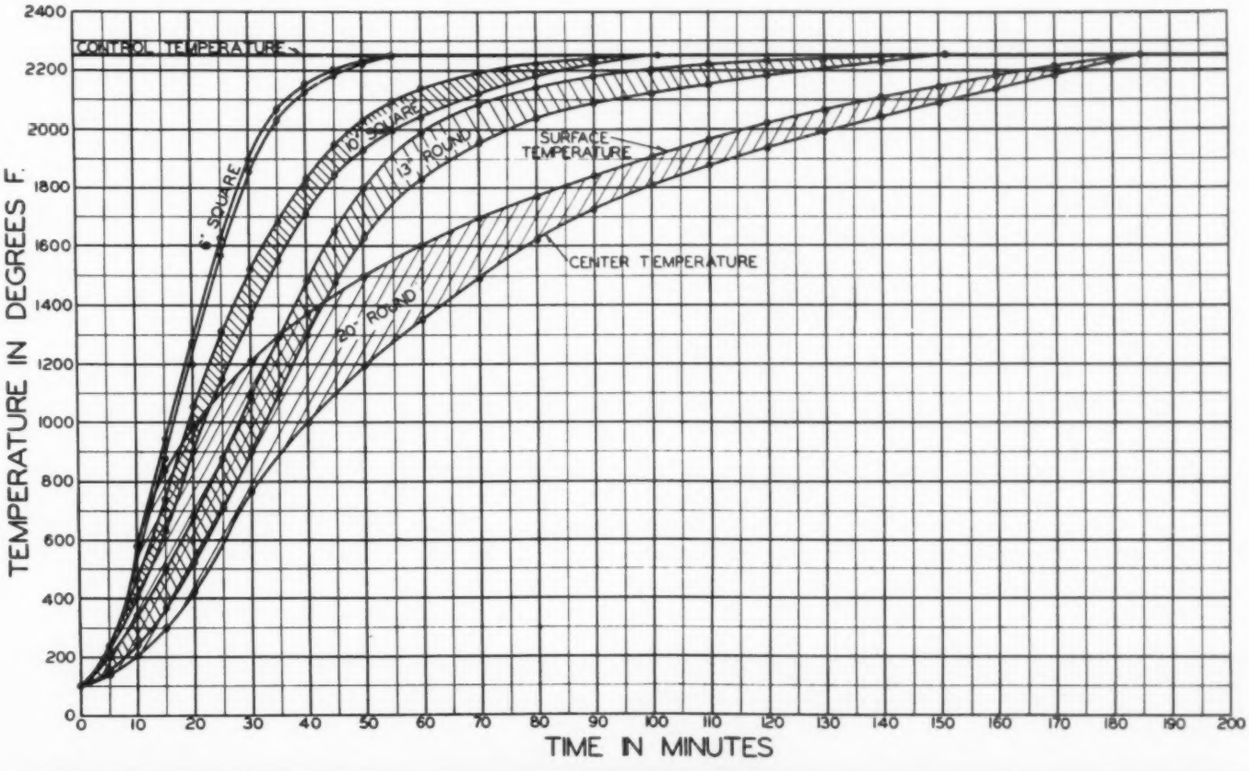
You may feel that heating rates shown in Figure 1 are too fast. These are actual test conditions which can be duplicated. If we were to increase furnace temperature by a higher thermal head in the early part of the heating cycle, still faster heating rates could be expected. Very accurate temperature regulation as now being developed makes possible improvements in our fuel application. Damage to steel in heating is not caused by fast heating but by over-heating.

BASIC FURNACE DESIGN FACTORS

We have shown in Figure 1 how steel absorbs heat, but before we consider a specific furnace design, let us state a few recognized facts which all furnace designs should satisfy:

1. The basic justification for the continuous billet heating furnace is the low stack temperature. The waste gases after leaving the hot zone are used to preheat the incoming material. Structural design which lowers the stack temperature without limiting furnace capacity makes a more efficient heating unit.
2. The impingement of flame on hot steel should always be prevented.
   a. Steel is burned and washed by being overheated. We know our flame must be hotter than our fur-

Figure 1—Heating curves, showing surface and center temperatures of steel from actual test measurements.



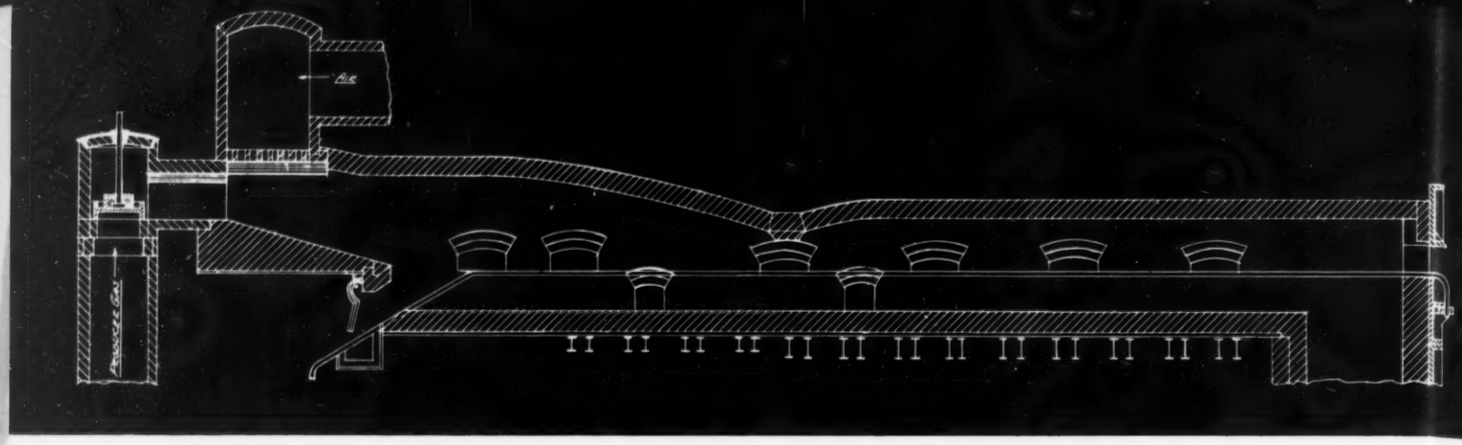


Figure 2—Design of splite flame continuous furnace burning producer gas.

nace walls. If our furnace design directs our hot flame against steel ready for rolling, it will be overheated where the flame strikes the material.

b. The quickest way to heat steel is by direct flame contact. This contact is, of course, local or spot heating. Some short furnaces heat almost entirely by flame contact because it is a method for getting tonnage from a poorly designed furnace. Material heated in such furnaces is usually thin, 2½ in. or 3 in. billets. From our temperature chart on heat distribution in steel, we can readily see why this condition is allowed to exist.

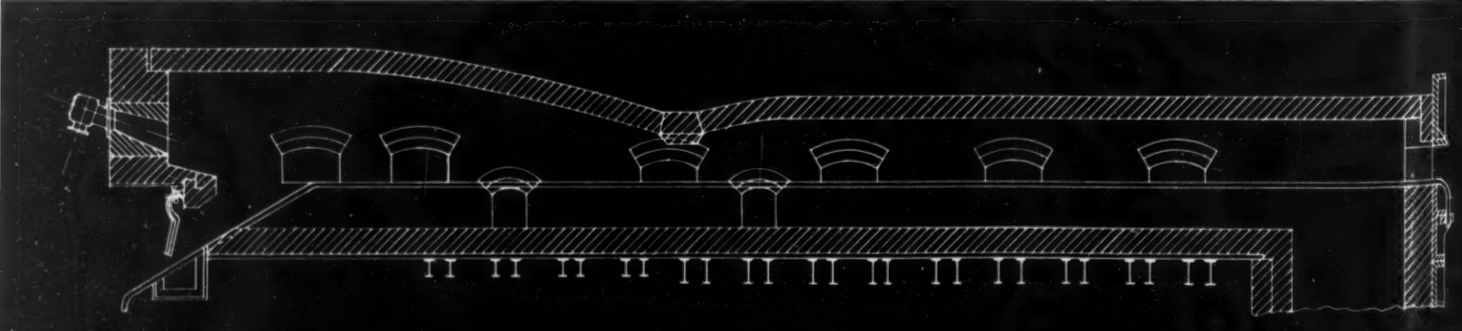
3. Heat is transferred to steel by radiation from furnace brickwork and flame, and by conduction from furnace gases. Conduction is a very small source of heat transfer in a high temperature furnace. The radiation of heat to steel can be obtained with either a clear or luminous flame. With the clear flame, the furnace interior radiates most of the heat, while with luminous flames the flame radiates most of the heat. The selection of the type of flame is thus dependent upon how material is exposed to radiation from flame and brickwork. In the continuous billet heating furnace, the brickwork area is small in relation to furnace hearth area, and thus one of the principal reasons for the success with luminous flames.
4. Radiation of heat within the furnace chamber should be considered in furnace design. This is an important item for it effects temperature distribution and accounts for good and poor results in furnace operation. For example, if we have a definite restriction in our roof contour, we get a hot zone in our furnace, and beyond the restriction the furnace temperature falls off rapidly. If we eliminate this restriction or move it further back in the furnace, we get an increase in temperature in the back of the furnace, with a decrease in the hot zone. In observing your furnace operation, keep this factor in mind. Some operators have constructed brick dampers within their furnace chambers so that this radiation could be controlled.

Figure 3—Section showing changes to port end in changing over to fuel oil or high Btu gas.

TYPES OF CONTINUOUS BILLET HEATING FURNACES

Split flame fired furnace—With the curves of Figure 1 in mind, let us analyze some of the existing steel mill billet heating furnaces. Figure 2 shows the design of the split flame fired continuous furnace. The original split flame fired furnace was fired with producer gas. How does this furnace satisfy our conditions for well-heated steel?

1. Producer gas comes through a long sloping port, which is directed against the steel.
2. The furnace roof is low to force gas under steel billets. This causes:
   a. Poor pre-heat because flame cannot get back to stack end.
   b. Hot flame hits hot steel and causes washing and burned steel.
3. Major heating must be done at furnace discharge.
4. If low temperature steel rolling, 2150-2200 F, is possible, this furnace can work at low capacity with good results.
5. The furnace always smokes because heater must delay combustion with deficiency of air to prevent high flame temperature on hot steel, and to get some heat back in furnace for preheating.
6. With producer gas, this furnace worked best because air for combustion was put on top side of the gas flame, and additional air comes up the discharge



slot to the bottom side of the flame. Thus, hot steel was not hit with flame of maximum temperature.

7. For delay periods this furnace was not flexible. If the producer gas and air is turned down, the flame would rise to the roof and the air coming up the discharge slot causes the first billets at the discharge point to become cold. Consequently, the heater finds, by long experience, that to keep the steel at the discharge point at a proper temperature for rolling, he must not reduce his fuel below a certain limit. The air is reduced to a minimum and the heavy flame floats through the furnace with great clouds of smoke going out the stack.

With the use of clean fuels, such as coke oven gas, natural gas, oil and tar, many of the original split flame fired furnaces were changed to another fuel. This has brought up a number of problems, none of which have been solved without completely rebuilding the existing furnace. Many of the original installations for coke oven or natural gas put the fuel in through pipes in the old producer gas brickwork and used the air system as it existed. Like producer gas, this method was not controllable and extremely high fuel rates were encountered, with the same conditions existing as went with the producer gas furnace.

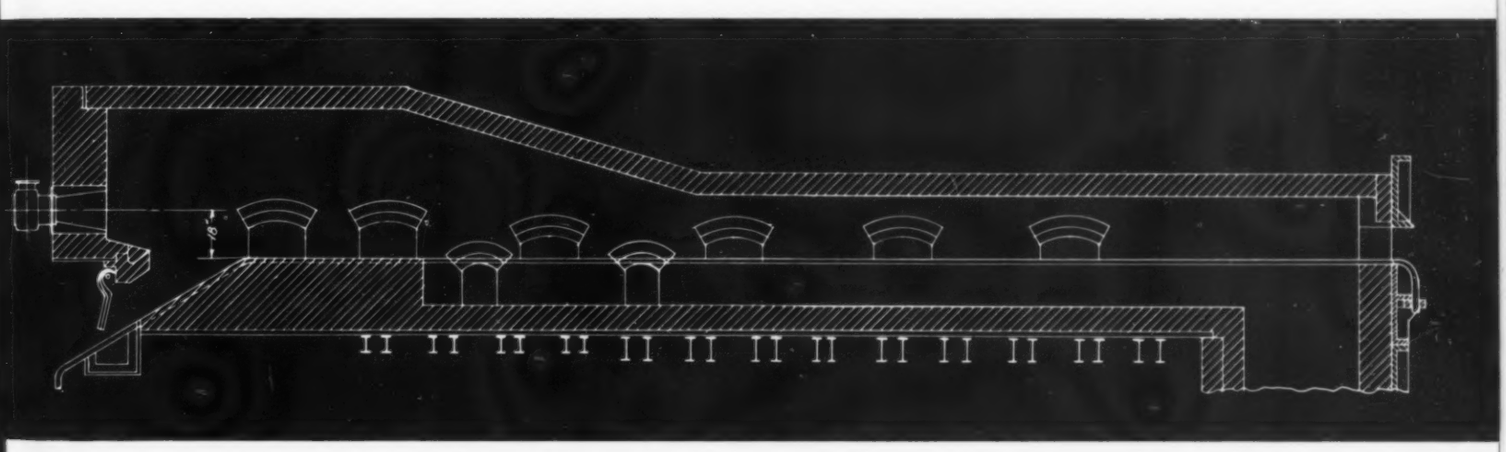


Figure 4—Single-zone furnace with short solid hearth, eliminating underfiring.

The port end of this furnace, on many jobs, was rebuilt and gas and oil burners installed, as shown on Figure 3. This method was not very successful, because:

1. Fuel burners worked at a higher velocity than the original producer gas furnace and created a suction upon the air coming up the discharge slot so that to properly operate the furnace only a small percentage of the air came in through the fuel burners. This, of course, changed the characteristics of the burner flame, and unless the burners were designed for this particular condition, the application was not very successful.
2. The location of the fuel burners to this furnace design was such that unless burners were tilted it was impossible to get flame underneath the steel. If burners were tilted, then the maximum temperature flame hit the hot steel unless delayed combustion burners were used. Long flame burners have a chance to partly correct the disadvantages of this furnace design because it is possible with proper burner selection to delay the burning so that maximum flame temperature is beyond the point where highest temperature steel is present.
3. The spaces between skid pipes on the original furnace were open. If the flame from the burners did not hit underneath the steel, then there was no way for air which came up the discharge slot to be consumed. Consequently, operators soon found that with the direct-fired burners, the furnace worked best with a short section at the furnace discharge blocked up entirely. Hence, if the fuel could not be forced underneath the steel, it is better to have the steel on solid brickwork.

Single zone furnace—Figure 4 shows the rebuilt split flame fired furnace. How does this rebuilt furnace satisfy our steel heating curve?

1. Burner flame does not hit the steel.
2. Roof can be elevated so higher preheat can be obtained in charging end of furnace.
3. Quality heating is obtained by longer hot zone.
4. Elimination of underfired heating reduced the furnace capacity.
   a. Water cooled skids were present without any means for getting heat under billets.
   b. Steel heated from one side only, thus making a cold bottom side and a reduced rate of heating.

Two zone furnace—The next logical step which was immediately recognized was that burners must be added to fire underneath the steel to control the temperature on the bottom side of the billet and to heat the steel from two sides. This gives us the two-zone fired furnace, as it was originally designed. The bottom section of the furnace was lowered and burners installed. This immediately added considerable tonnage to the heating rate, with a distinct improvement in quality.

Figure 5 shows the development of the two-zone under-and-over fired continuous billet heating furnace.

This compares well with the conditions that should exist for well-heated steel.

1. The flame above the discharge point does not hit the steel, and temperature can be kept to suit steel conditions.
2. Capacity of the furnace is governed by the temperature which hot steel at the discharge will stand without washing. Long flame or delayed combustion

burners give more tonnage from this furnace, because it is possible to fix the hot spot at a maximum firing rate up the furnace beyond the hot steel.

3. The underfired burners fire under the steel at a point where the steel is cold.
   a. The greatest disadvantage to the underfired zone applications is that many old rebuilt jobs have been too skimpy. From our heating curves, Figure 1, we can see that the steel is capable of absorbing a large part of its heat at this point. The underfired combustion chamber should be large and the burner capacity at least 40 per cent of the total fuel required.

In summarizing, the changes that were apparent in this development with the application of direct fuel fired burners in the split flame fired furnace are:

1. Solid hearth was installed on the furnace to prevent skid marks.
2. Burners were installed in the front wall to prevent flame impingement on the steel.
3. Roof in the discharge zone of the furnace was raised for larger combustion volume and to give a longer hot zone.
4. Burners were installed to fire underneath the steel.

This furnace was found to be a large improvement over the original design, but it left something wanting for high tonnage operation. The advent of the luminous flame or long flame gas burner with its uniformity of temperature and long flame length improved this condition. The long flame would keep excessive temperature away from the hot steel on the over-fired zone so that more heat could be driven into the cold steel in the pre-heat zone.

As mill tonnages were increased by the speeding up of our rolling mills, capacity of our furnaces became bottlenecks in our production schedule. In many cases space was not available for more furnaces. Consequently, furnace length was increased.

Three zone fired furnace—The third progressive step in the two-zone fired furnace for longer length furnaces was the design of the triple-fired furnace. Its advantages over the two-zone fired furnace are readily apparent from the study of the respective sketches. With the two-zone fired furnace, the main difficulty was in maintaining the proper condition of steel at the discharge point for all mill operations. With the advent of the triple-zone fired furnace, Figure 6, it was possible to move the high capacity burner from the discharge point towards the charging end of the furnace and to have a solid hearth which was controlled by a set of burners which did not operate over a large range of capacity. Therefore, in a triple-fired furnace of an end discharge design, the burners at the discharge point have a capacity which would just maintain steel condition at the discharge point of the furnace. The changes in furnace tonnage are entirely taken care of by the under and over fired burners in the zone where the steel is relatively cold and can absorb heat without damage.

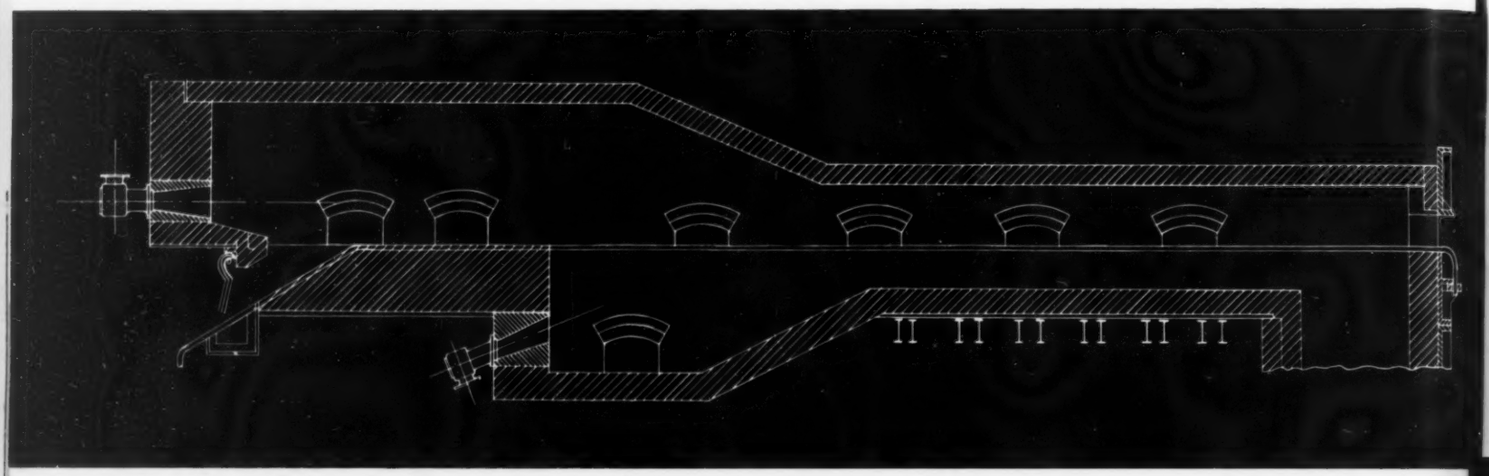


Figure 5—Design of two-zone furnace, with under-and-over firing.

The success of the three-zone fired furnaces can best be seen by studying the furnace temperatures in relation to steel temperature. As shown in Figure 1, a high rate of heat absorption is obtained by heating steel in a furnace of controlled maximum temperature. However, suppose we were to elevate the furnace temperature while the steel is cold, then we could increase our heat absorption rates without damage providing the steel when hot was not exposed to the high furnace temperature. This is the result which has been accomplished by a triple-fired furnace.

Figure 6 shows a three-zone fired furnace with furnace and steel temperature plotted in relation to its length on a given operation. Here we readily see that:

1. Hot steel, ready for rolling, is not effected by the rate of heating or high thermal head.
2. Heating rate is entirely dependent upon the rate of firing in main heating chamber.
3. Heating capacity of this furnace design has exceeded builders rated capacity. Many fifty-ton furnaces are heating sixty-five tons per hour.
4. Capacity of this furnace is entirely dependent upon combustion volume, available air supply for com-

bustion, and temperatures which refractories will stand.

Solid bottom continuous heating furnaces—The steel industry has a large number of continuous pusher type billet heating furnaces which are constructed so that the billets are pushed down hill. This type of furnace presents a very serious problem in the control of the heating operation, because the gases at certain rates of firing tend to rise to the roof, making this type act like so many stacks. The hydro-static effect of the hot gases creates an up-draft which is hard to control. If we study the furnace design which has been constructed for this type of heating operation, we can see the thoughts back of many of the engineers to correct the up-hill stack effect of this furnace.

Figure 7 shows an outstanding example of this type. Here we have the early thoughts of our engineers to develop a furnace to prevent air leakage into the furnace proper.

1. The furnace is side-discharged so that the openings which are under suction are small. In many cases these openings are opened and closed automatically for discharging billets to the mill.
2. This furnace is side charged and pusher arms come in through small openings in the back wall. Engineers knew that this section of the furnace would be under pressure so that they took every means to restrict the outward flow of gases in the stack end and hoped that the damper could be operated to maintain desired pressure conditions.
3. This type of furnace construction was not perfect, for even with small openings at the charging end it was almost impossible to prevent the furnace gases from blowing out and making a bad working condition for the men; and automatic damper regulation has not been any too successful because it is not practicable to maintain zero pressure at the discharge door.

Attempts have been made to restrict the hydro-static flow of hot gases in this up-hill furnace. The method of attacking the problem is to restrict the flow of gases within the furnace proper before too high a static pressure is developed. If sufficient frictional resistance to the flow of gases up the furnace is installed, then it is possible for the stack damper to be raised in order to pull the gases through the restriction. Thus, we can get a balanced pressure at the charging end of the furnace and a balanced pressure at the furnace discharge.

Figure 8 shows an arrangement which has been in operation. In this particular design, the roof in the main combustion chamber was raised to keep the flame from the burners off the steel and to give a more uniformly-heated hot zone. The roof of the furnace from

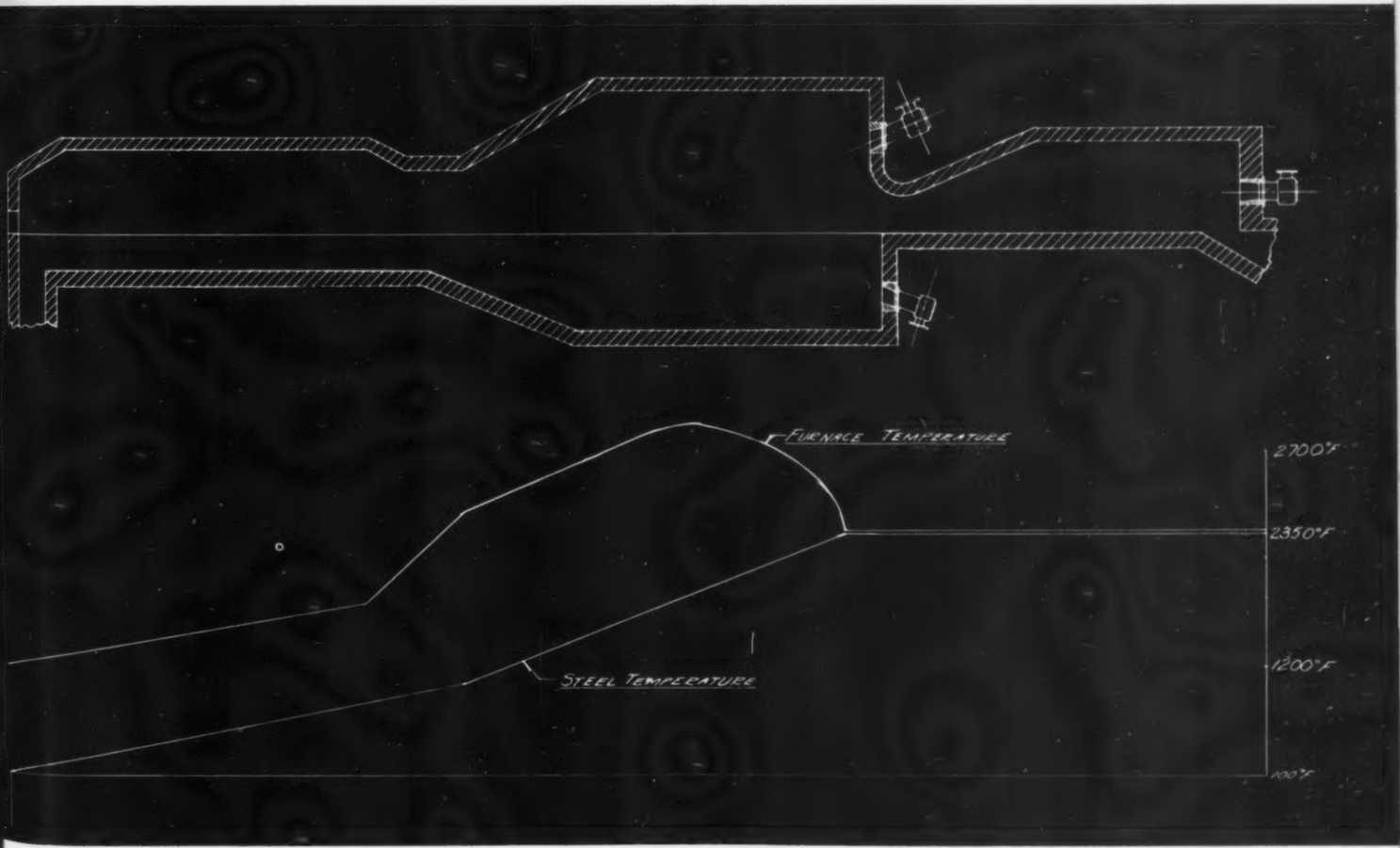


Figure 6—Sketch showing design of three-zone furnace, with existing temperature relations.

the middle of the furnace back was lowered to set up a uniform frictional resistance to the flow of gases. The operation of this furnace design indicates that it was well worth the effort.

1. The balanced furnace pressure could be maintained at the push out door.
2. Steel was uniformly heated in the larger combustion zone.
3. The air leakage into the furnace was not more than 2 or 3 per cent of that required for combustion.
4. Thermal efficiency of the furnace was improved because with the higher roof construction we were able to get a higher, more uniform hot zone temperature; and if we refer to Figure 1, we would realize that such a furnace working with 2 in. billets can absorb heat at a very fast rate. With the lower roof high velocity section at the back end of the furnace, the temperature of the waste gases dropped off quickly, and the operators were not worried about overheating the steel in the back end.
5. Low roof restriction reduced radiation losses from the furnace hot zone and further reduced the waste gas temperature.
6. Working conditions at the charging end were improved by preventing the gases from blowing out at the charging doors.
7. This construction does not reduce furnace capacity; if anything, capacity is increased.

Seamless mill furnaces—It is quite a simple matter to get engineers to agree to lower the roof in the back end of a continuous billet heating furnace. However, there are a great many other types of furnaces which push or roll the material down-hill and which could be improved by thought of similar nature as that used in the billet heating furnace. The long seamless mill of piercing mill reheating furnaces need this similar construction. These furnaces are generally 80 ft long, with high roofs and a very pronounced down-hill sloping hearth. Along the sides are a great many small doors through which workmen must work rolling the product down the hearth. Like the billet heating furnace, most of these furnaces are side-discharged but are end charged. Invariably, the doors at the charging end are burned away in the first months of operation. The stack temperatures are extremely high.

Figure 9 shows an arrangement by which the stack effect of this furnace has been controlled. The roof of the furnace has been dropped for a short section about midway between the charging and discharging openings. The results of such a design are:

1. Furnace pressure can be controlled to a balanced condition at the discharge door without excessive pressure at the charging door.
2. Air required for combustion as measured going through the burners before the change was 50 per cent. After the change, the air required for combustion going through the burners was 100 per cent.
3. Temperature in the hot zone was materially improved. It is found that by bottling up the furnace, radiation from the hot zone was decreased and that a much more uniform furnace temperature can be obtained throughout the entire main heating zone.
4. Like the results in the billet heating furnace, waste gas temperature was dropped on the furnace approximately 400 to 500 F.
5. Marked reduction in the fuel per ton of product heated was noticed.

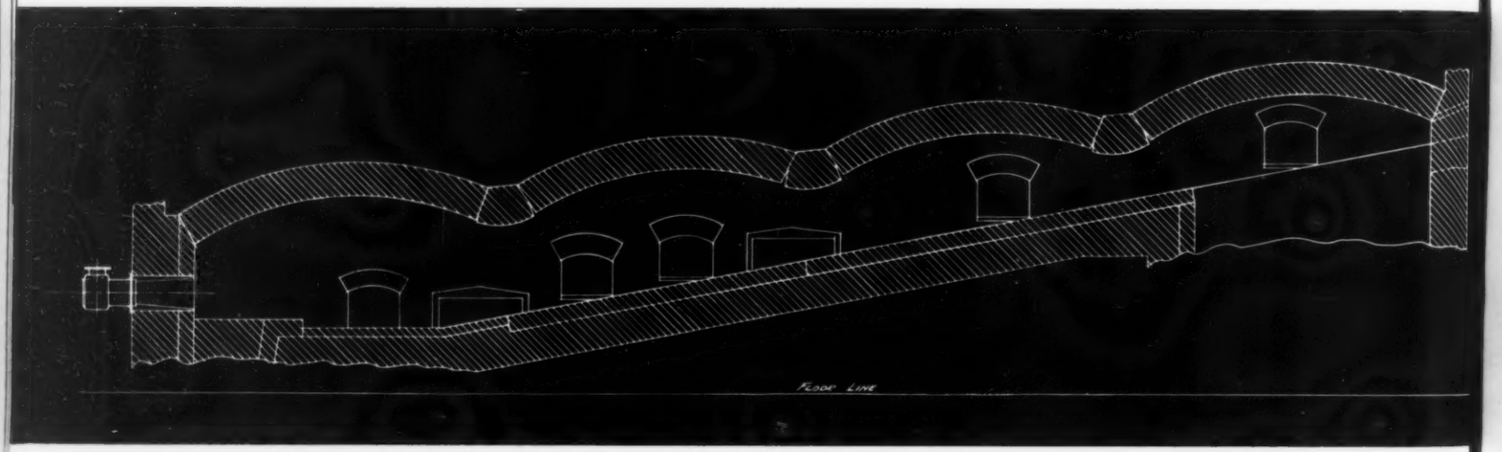


Figure 7—An example of solid hearth furnace, with steep slope on hearth.

6. Furnace capacity was not changed.

Batch furnaces—The steel mill heating operations are almost entirely confined to either continuous pusher type or to batch type heating furnaces, such as soaking pits or side door heating furnaces.

Soaking pits have been given considerable thought in the last ten years, and many improvements have been incorporated. However, without attempting to discuss the merits of the various types of soaking pits, let us again refer to Figure 1 and take an open view of our batch heating problem. The steel heated in Figure 1 can resemble the conditions in any soaking pit, but the rates of heating are much faster than we get in our commercial soaking pits. We would not expect to heat cold steel 20 in. in diameter in a soaking pit in three hours, but still we have shown that this condition can

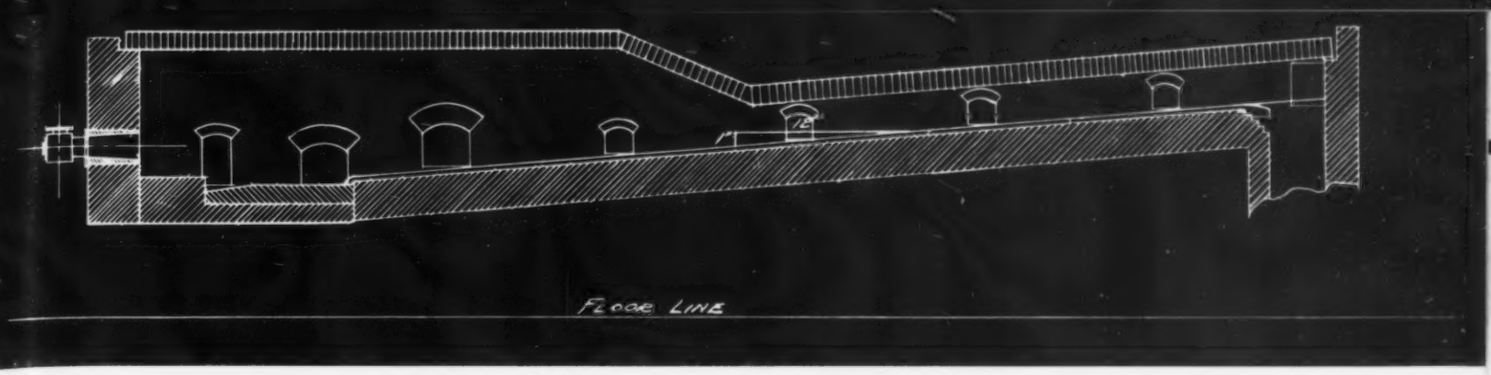


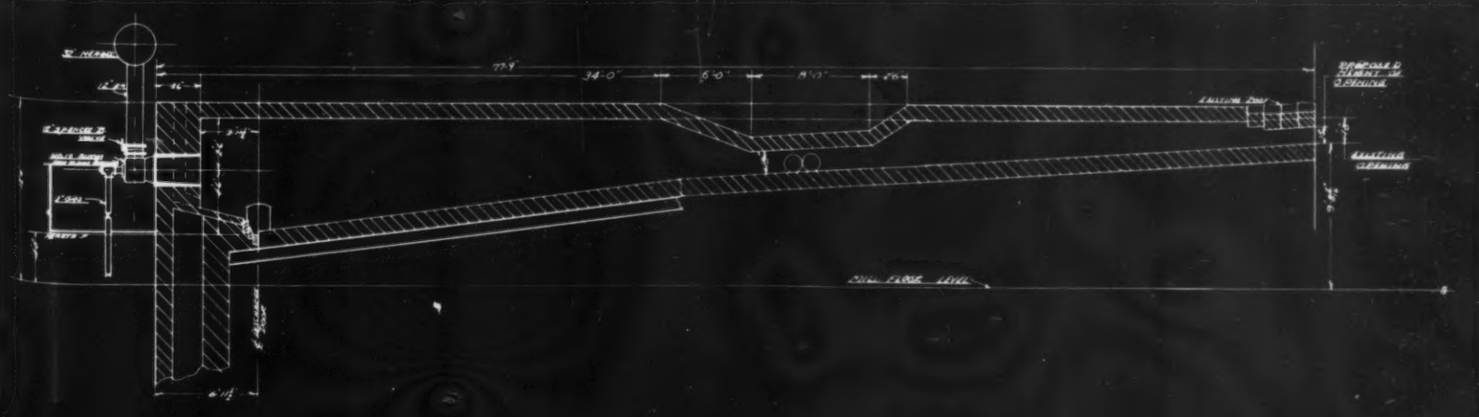
Figure 8—Lowering of the roof in back half of this furnace greatly improved operation.

be accomplished; and with still further reference to Figure 1, suppose we were to increase our furnace temperature at the early parts of our heating cycle. Then we would expect to heat the 20 in. ingot in a much shorter length of time. I believe you all agree that for soft steels this could be done without hurting the steel, providing the furnace temperature was again reduced to a desired point as soon as the surface of the steel became hot. This may be the ultimate in pit operation or design, but to understand our full problem let us attack the conditions from the standpoint of why a commercial furnace will not duplicate our test operations.

If we look at the triple-fired furnace, we find that its design, in many cases, will duplicate our test conditions; so why operate the bacth heating furnace at so much lower rates?

1. Our pit temperatures are not uniform. We recognize this to be the case in the regenerative pit, but we compensate for it by reversing the pit. With our so-called one way or recuperative pits, our temperature must not be uniform throughout the heating cycle.
2. Pit temperature is not maintained uniform from the start of the heat. This is to be expected, because we hardly charge a pit with cold steel and expect to have our pit up to temperature as soon as the cover is replaced. However, many of our modern pits require too long to get up to temperature, and we do not duplicate the conditions that were experienced in the test operation. We can all realize that pit capacity can be increased by getting our pit up to temperature as quickly as possible.
3. There are definite limits and draw-backs to decreasing the time required to get the pit to maximum temperature.
   a. Maximum limit for speed is governed by the combustion volume of the furnace. In many of the old regenerative pits the volume is so restricted by the number of ingots charged that only a given amount of fuel can be burned.
   b. In new type pits the quantity of air or fan size provided, the size of the recuperator, and the size of the stack will not afford burning more than a given amount of fuel.
   c. There is a distinct hesitancy on the part of all operators to push the heating in the new type of pits.
4. As shown in Figure 1, provided steel surface is not hot, thermal head between steel and furnace temperature will not hurt the quality of the normal product. The great majority of poor pit heating is caused by flames at high velocity impinging on hot steel surfaces. This can be corrected.
   a. With uniform pit temperature, burners will not be firing at high capacity when steel is hot. There will be no need to have high fuel input to bring up cold sections. Low burner velocities will not cause washing.
   b. With a non-uniform heating condition, we should get our pit up to temperature as quickly as possible so that firing rates can be reduced before any steel surface is at pit temperature and thus eliminate high velocity flame impingement on hot steel.
   c. If we study our heating practice carefully, we will generally find that the steel is washed midway in the heating cycle. The steel surface is overheated at that time when ingot surface temperature approaches pit temperature. If pit temperature is not uniform, certain ingots come up faster than others and are therefore exposed to high velocity flame impingement when the surface is hot. We have observed soaking pit heating where cold steel was washed inside of three hours after being charged. The top of the ingot was hot and the bottom cold.
   d. Measurement and control of temperature is the

Figure 9—Installation of short constriction in roof improved regulation of tube mill furnace.



major factor for obtaining quality heating on any type of pit. It is the first step in obtaining improved quality of operation. The temperature we desire to measure is steel temperature, but no equipment has yet been devised to do this while the furnace is full of flame. Perhaps we should consider devising a means of operation by which steel temperature is actually measured. As it is now, we get an average temperature of flame, wall surface, and steel. This is an improvement over manual operation, but in many cases we retard production because our temperature measurement is not true. Any modern pit must lend itself to dependable temperature measurement. The use of automatic temperature regulation makes it necessary to use fuel-air ratio and furnace pressure regulation. It is foolish to expect a heater to manually adjust these operations in step with fuel changes as demanded by temperature Combustion ratio control and furnace pressure control are tools to be used to produce uniform pit temperature. With temperature control, they should replace our heaters. This system is not perfect. We sacrifice tonnage for quality. Too often we look at the temperature and fuel flow charts while we should be looking at the steel in the pit.

e. The modern soaking pit is incorrectly named. It is a heating pit. The soaking period in any heating cycle is not caused by non-uniformity between inside and outside steel temperatures, but by unequal temperatures of the ingots or sections of the same ingot. When the surface is uniform in temperature, any ingot can be rolled.

The modern soaking pit has good reason for being a superior furnace.

1. The combustion volume has been increased.
2. Circulation between ingots is better.
3. Automatic controls have been applied.
4. Clean and controllable fuels are used.
5. New pits are designed for the present ingots which do not suit the old pits.

Where can we expect further improvement in our soaking pits?

1. Improve the uniformity of our pit temperature. This will come about by a better burner design. Already much progress has been made in this direction.
2. Improve our temperature measurement.
3. Increase our pit fuel burning capacity. In many cases our fans, recuperators, burners, etc., are not large enough for the capacity which should be heated.
4. The pit of tomorrow will be able to heat 60 per cent more steel than the pits of today.

PREHEATED AIR

The value of pre-heated air is quite well understood. It is more useful on a batch operation than it is for the continuous furnace, because stack temperatures are so much higher and the combustion volume so much more limited. Theory indicates that savings in fuel as high as 40 to 50 per cent are possible by pre-heating air. However, this should not be considered a deciding factor for the use of air pre-heating. With a definite batch furnace design, we have a certain combustion volume available for the burning of fuel. With pre-heated air we can get the same amount of heat delivered to the chamber with 40 per cent less gas and 1200 F air as we can with cold air, but if our combustion volume is limited, we can get 40 per cent more heat given up in a definite combustion volume with pre-heated air than we can with cold air. Fuel savings are very gratifying to our fuel engineers, but speed of heating and tonnage from a given space is much more important to the plant management.

Today our heating furnaces are being built more and more with recuperators. We have improved the recuperator structure by the use of better materials. We have

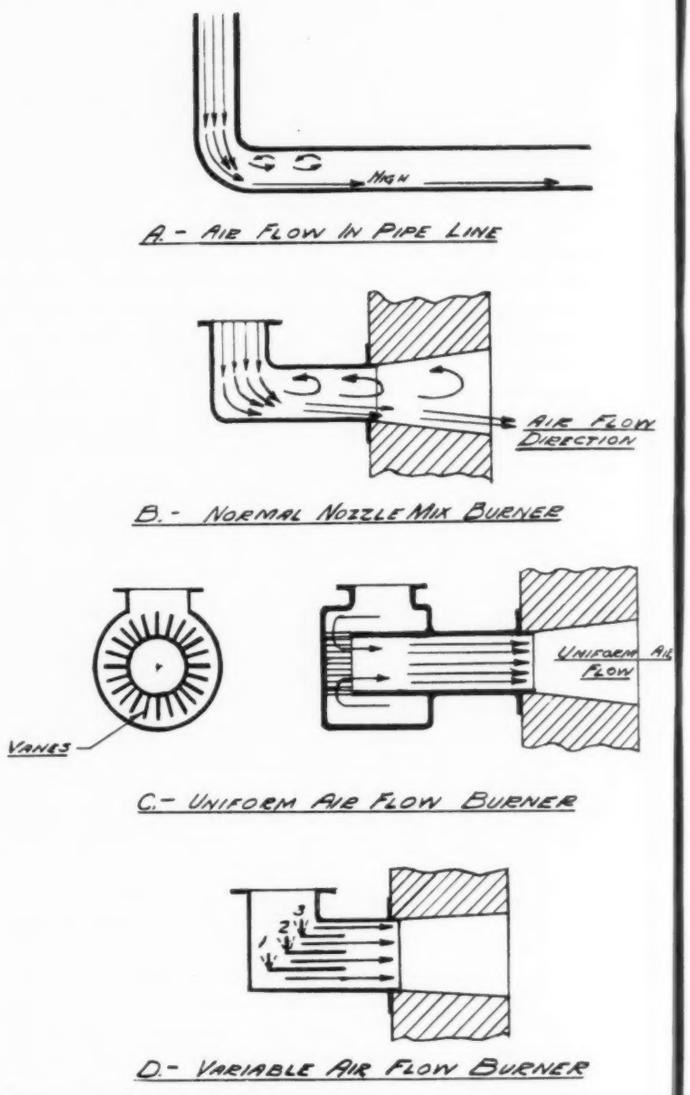


Figure 10—Sketch showing conditions of air flow common to all nozzle-mixing burners.

installed hot fans to exhaust the air from the recuperator to assure positive air supply. However, the success of our present modern furnace depends upon:

1. The structure and heating elements of our recuperator must be maintained. The operation of a present-day furnace depends entirely upon the complete unit, furnace, and recuperator being maintained in operating condition. The operators of our furnace equipment must realize that is is just as important to maintain a recuperative air heating system as it is to maintain a regenerative air heating system. The recuperator should be considered as much a part of the furnace as is the regenerator.

2. Pre-heated air requires more careful engineering of the fuel application than does cold air. The air pressure available with either the push-through or pull-through type is low. The design of our air duct system and our burners must necessarily be such that flow restrictions are kept to a minimum. Our experiences with recuperative air systems show that they fail because sufficient air was not available for the proper operation of the furnace, and the operators would rather accept high fuel costs than low furnace tonnage.

3. The design of pre-heated air fuel burners has been neglected because all burners tend to set up a certain definite restriction to air flow. The original recuperative hot air system was designed on the basis of .1 in. total air pressure. Normally the hot air was brought through brick ducts to the furnace port and left to take whatever course or direction it could. In many cases fuel at the burner port was used to create a suction upon the air flow in order to help get the air into the furnace. Everything was engineered to attempt to get the air into the furnace; consequently very little thought could be given to the type of flame or speed of burning which should be designed into a burner system. We all realize that this condition has penalized our furnace operation and our fuel economy. In many cases we have furnaces using cold air and proper burners which give tonnage and fuel results comparable with identical furnaces using pre-heated air. This should not be true, if our theory of pre-heated air combustion is correct. The drawback of our pre-heated air systems in many cases is in burner design.

BURNER DESIGN

The problem of burner design and selection is not simple. Burners should be designed to obtain a result in a given furnace. The design of the furnace chamber, as we have pointed out previously, has a marked effect upon the rate and quality of our heating operation. Burners should be designed to produce a condition in a specific furnace which suits the design of that furnace and its operation under all conditions. The flow of air to a furnace or through a given set of burners is the basic factor in burner design. Even though we have many types of burners on the market today of various designs and manufacture, we can divide them, for metallurgical furnace application, into two classes, premix burners, and nozzle-mix burners:

1. *Premix burners*—This class will cover high pressure gas inspirator burners, and air-gas induction burners or proportional burners. The entire group is concerned primarily in obtaining air-gas proportions. The high pressure gas inspirator obtains its air-gas ratio by the particular design of venturi tube and spud size. A proportional mixer obtains its air-gas ratio by a venturi tube through which air flows and creates a suction upon the gas which is maintained at atmospheric pressure. Both types are entirely satisfactory in obtaining fuel-air ratio. All burners of this type must necessarily have a premixed gas-air mixture at the burner nozzle or port block, and the resultant flame is clear. The fact that this air-gas mixture gives a clear flame is secondary, and is a result more than the cause for flames of this system.

2. *Nozzle-mix burners*—All other forced draft burners can be classed as nozzle-mix burners, because the fuel and the air are brought together in the burner proper at the furnace wall or port block. This classification covers all our powdered coal, oil, and gas burners. It is the predominant system used for the application of fuel in metallurgical heating furnaces. This is a logical conclusion because so much more can be accomplished with a nozzle-mix burner than can be accomplished with a fixed air-gas ratio burner. If we review our metallurgical furnaces, we will find that due to the furnace design, many of our old furnaces will not function with correct fuel-air ratio. The fuel-air ratio must be under the control of the operator, which is so easily accomplished with the nozzle-mix burner. There are a great many designs for nozzle-mix burners, but in all cases the design is made to obtain a type of flame in the furnace. Some flames are required to be quick-burning, while others are designed to be slow-burning. We cannot attempt to discuss the merits of nozzle-mix burner design, but the air flow in all nozzle-mix burners does have a common relation, and influences many of the results obtained from their application. Figure 10 shows the conditions of air flow which are common to all nozzle-mix burners.
   a. Item A, Figure 10, shows the typical flow of air in a pipe line after a right-angle bend. The air, regardless of velocity, always hugs the outside of the right-angle bend and it is necessary to go at least six diameters down-stream before uniform flow is established. If we were to take orifice measurement in a pipe line, we would have to go at least ten diameters in order to get away from turbulence and to get in a zone of uniform flow.
   b. Item B, Figure 10, shows how the air flow acts in the elbow of a nozzle-mix gas burner. Similar to the air flow in our pipe lines, the air flows to the outside of the bend, and in many cases follows an entirely different direction from that followed by the fuel. If we observe the application of nozzle-mix burners to a furnace, we will note in many cases that the air does not follow our fuel stream or does not go where it was directed. It is the cause for many of the unsatisfactory conditions which are experienced in our metallurgical heating furnaces.
   c. Item C, Figure 10, shows a means which is successful in straightening our air flow. In this case,

the initial velocity of the air is partly destroyed by discharging the air into a plenum chamber. From this chamber the air is discharged uniformly through a U-bend arrangement. In flowing over the lip of the baffle, the air must go through a series of directional vanes so that air entering the main chamber is directed uniformly against air flowing from the opposite side. The air thus straightens itself out and flows uniformly in the main passageway from the burner.

d. With the arrangement shown in Item C, we get uniform air flow; but in many cases in the application of burners to the metallurgical furnaces, we may not want uniform air flow. Arrangement D of Figure 10 shows a method by which the air flowing through a nozzle-mix burner may be changed to allow more or less air to be on the top side of the fuel stream. In this arrangement, vanes are installed similar to straightening vanes in the elbow of an air pipe, except that the one part of the vane is movable. It is possible by adjusting baffles 1, 2, and 3, to direct air in a horizontal direction through one passageway at a higher velocity than in another passageway.

The study of our furnace design will indicate that many of our continuous billet heating furnaces can be improved by changes in the method by which our air enters our furnace. In some cases we may wish to blanket our steel with a gas flame which is not too hot and in such cases we prefer to have a large portion of the air on the opposite side of our gas stream rather than uniformly surrounding our gas stream. In other cases, the furnace design may demand that the air flow be absolutely uniform on all sides of our fuel stream.

The latter condition is essentially true on stationary or batch furnaces where the steel is exposed to the same temperature distribution at all times throughout its heating cycle. If conditions are not exactly right in the burners, we can provide no means in our furnace design for moving the steel and thus exposing it to another set of temperature conditions.

DISCUSSION

PRESENTED BY

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R. I. GUMAER: In covering the subject of fuel application in metallurgical heating furnaces, Mr. Bloom has presented a new point of view, at several places, which should help to correct some common misconceptions regarding heating practice. Many a dollar has been spent on automatic combustion controls, furnace pressure controls, recuperators, etc., which gave promise of large fuel savings, only to find that through some fault in furnace or burner design, the furnace had to be operated pretty much the same as before the improvements were added. It is becoming more apparent that fuel economy, production rate and heating quality are factors which must be designed into a furnace, and are not necessarily obtained by merely adjusting air-gas ratios, holding constant furnace pressures, or using higher preheats. The ideal furnace is the one in which air and fuel can be made to flow in their proper proportions, at a rate to produce desired tonnage, and in such direction as to secure most uniform heating of the product.

Mr. Bloom mentions that the basic justification for continuous billet furnaces is the low stack temperature with attendant fuel economy. This thought cannot be emphasized too strongly. As shown in his data, uniform heating with maximum production rates calls for rapid heating with large temperature differences between furnace and steel while the steel is cold, with a reduced differential as the steel approaches final temperature. For this effect, the counter-flow principle of the conventional continuous billet furnace is all wrong. For this reason, a considerable portion of the charging end of the average continuous billet furnace should be written off as a heat salvage device, just as though it were a recuperator or waste heat boiler. It should not be counted on as usable heating area in comparing effective square foot heating rates with those obtainable in a constant temperature batch furnace.

In a study of heat transfer between furnace and steel, consideration must be given to the insulating effect of the ever present layer of scale on the surface of the billets. It has been reported that the outside surface of the scale can be from 120 F to 540 F hotter than the surface of the steel beneath the scale. This means several things. First, it accounts for the smaller than expected temperature differences between the center and surface of steel billets, when these temperatures are taken with thermocouples. It indicates that radiation or optical pyrometer readings taken on the surface of the scale are erroneously high. The scale layer thus has a beneficial effect in preventing overheating of the steel, so long as it is present. However, if heating is too rapid as the steel nears final temperature, it is quite easy to exceed the melting point of the scale, which is around 2400 to 2500 F, thus removing the protective action. When this occurs, the surface of the steel not only becomes hotter, but new scale is formed rapidly

at the temperatures then prevailing, resulting in a still greater metal loss.

Mr. Bloom has presented some reasonable arguments for greater initial firing of batch heating furnaces such as soaking pits. One problem here is that the greater we make the rate of firing at the start, the greater will be the range of turndown at the finish. Proper firing over a large range of turndown is difficult not only from a standpoint of burner design, but also from the standpoint of uniformity in the heating chamber. A furnace having a large volume to accommodate heavy-firing at the beginning of heat is difficult to heat uniformly with the small amount of fuel burned at the end of the heat.

Some batch heating furnaces can take advantage of this condition by heating one part of the charge at the higher rates of firing, and the balance at the lower rates. However, this is not a good condition when the charge must be held for a considerable length of time after it is ready for drawing.

It would seem the ideal solution would be to maintain a constant firing rate, while reducing the flame temperature or Btu of the fuel as the charge approaches temperature. In other words, qualitating rather than quantitating control of fuel. Where a high percentage of excess air is not injurious, this may be done, by holding the air constant, while reducing the fuel. The use of varying proportions of a rich fuel and a lean fuel is another possible solution.

F. S. BLOOM: Mr. Gumaer has brought up a number of serious problems. We agree that too often money is spent for burners, temperature, ratio, and furnace pressure controls without receiving proper savings in return. We also know that each of these items will, in most cases, pay their way. The usual fault lies in application. Furnace auxiliaries such as controls, burners, recuperators, etc., must be engineered into a furnace design. If an existing furnace design is not right, then we should not attempt an application unless furnace design is corrected.

Engineers selling and recommending auxiliary furnace equipment can improve this situation by being more careful with each application. The better the control and the burner engineers understand furnace design and operation, the fewer cases there will be of no improvement.

Mr. Gumaer gives us some very good reasons why soaking pits do not heat as fast as our test curves indicate. As engineers, we have the conditions to correct. It means we need better burners, better control, and above all, better application of these items in conjunction with furnace design. Mr. Gumaer suggests lowering the Btu content of the fuel during soaking periods. Certainly this would be a step in the right direction.

E. E. CALLINAN: I think Mr. Bloom served us a point worth considering when he emphasized the fast heating rates which can be reached in safety provided furnace design and control equipment are proper and adequate for the job. Recently we ran a test on 10 in. round billets in which we measured the temperature at the top, middle and bottom of the rounds which were resting on a solid hearth and heated by burners on the top side only. The billets were not turned over on the hearth during the heating.

Briefly, the test indicated that 10 in. round billets could be heated very uniformly in 2¼ to 2½ hours; which is definitely less than the general rates cited in most text books, 20 minutes per inch of diameter. This rate is not as fast as the 10 minutes per inch of thickness cited by Mr. Bloom, but is approaching it. It is believed that further regulation of the burners and the temperatures employed would have produced a further increase in the heating rate.

Referring to Mr. Bloom's remarks on the slow rates of heating prevailing in soaking pits, I believe there is another point to be considered in this problem. Most pits involve certain compromises in design, just as the port end of an open hearth is generally a compromise with respect to the widely different conditions existing when it is an entrant passage half the time and an exit passage the rest of the time. Most pits have a single large burner or flame source, which, I believe, limits the fuel input rate, and tends to control the length and character of the flame, and increases the furnace volume required to produce the desired heat release. On the other hand, the slower combustion and simplicity of design and control of the single burner pit produces some benefits which otherwise might not be obtained.

I would appreciate hearing Mr. Bloom's comments on burners which are designed to re-introduce waste gases into the furnace, thereby maintaining constant volume and velocity and giving further control of flame characteristics.

F. S. BLOOM: Mr. Callinan brings up a kind of a tough point to be discussed. I can't answer this definitely, but we have certain experiences to go by. We know if we get waste gases in our combustion air, and quite a few steel plants have run into this condition where suction fans draw air through a recuperator, and thus get stack gases due to leakage sucked into the air, that the combustion is not right. Waste gas in the air will delay our combustion, but we also do not get the flame temperature we should. I can see possibilities of putting waste gases back into our burner for low rates of fuel input, but I think in all cases we are going to make our furnace operation worse by doing so than if we were to continue to operate with either an excess or normal air for combustion and have a slow circulation in the furnace proper rather than putting the waste gases in to keep up circulation.

We seem to be stressing the wrong principle in regard to uniform heating in our pits. The low velocity circulation at low fuel input does not hurt our pit operation. The pit actually becomes uniform in temperature with fuel input at low flow. All damage to the steel and poor temperature distribution comes while the pit is operating at high fuel flow.

I do not agree that we cannot make our pits operate faster. Most pits today are fairly uniform in temperature if soaked long enough. The one point we have not solved is that the pit is not uniformly heated during the high firing period. Everything so far indicates that a more uniform pit temperature can be obtained by increasing fuel rates at the start of the heat and by delaying combustion so that the top of the ingots does not get hotter than the bottom.

J. F. TILTON: Furnaces in forging plants are generally heated with one of two types of fuels, namely, oil or natural gas. Both fuels can be controlled to secure

proper heating and proper atmospheres and producing a minimum of scale.

A study of the proper burners as well as location and ease of operation has brought forth the following facts.

A continuous pusher type, billet heating furnace some forty-two feet in length, with side loading and side discharge door is operated automatically from a thermocouple located in the extreme hot end of the furnace adjacent to the discharge door. The openings in the furnace walls are reduced to a minimum and the pusher arms operate through small openings in the end wall.

Automatic temperature control of a furnace means that the fuel-air ratio must be controlled over a wide range of turndown. Also that constant atmosphere conditions must be maintained, combustion must be complete to allow the heat produced to be distributed in a satisfactory manner. In any automatic device for the control of furnace atmosphere it is necessary that the ratio of fuel to air be capable of easy adjustment and likewise, once any adjustment is made in the fuel air ratio, it should remain constant during the automatic operation of the furnace.

The gas and air ratio is maintained, on the furnace just described, by means of a proportioning controller. This controller adjusts the flow of the air in direct proportions to the flow of the gas. This controller is easily adjusted to produce either oxidizing, neutral, or, a reducing atmosphere.

In forging practice it is most desirable to produce a scale on the billets which drops off easily, and is not hammered into the forging. To obtain this result the furnace is operated either in a near neutral atmosphere, or one that is slightly reducing, namely the air gas ratio is controlled between 9 to 10 parts of air to 1 (one) part of gas.

The gas burners are located on the roof of this furnace over the preheat chamber but firing into the combustion chamber toward the discharge end of the furnace. The long luminous flame emerges from the burner traveling about 15 feet to the end wall and is then depressed toward the hearth. The flame then completely covers the stock being heated and is burned out after traveling slowly about 40 feet over the stock and in the opposite direction of the movement of the billets. All firing is above the stock for the billets slide over a continuous solid hearth.

The stack damper which is manually operated is adjusted so that a prositive pressure of approximately .25 in. of water is maintained in the furnace. The automatic gas valve which is controlled from the pyrometer is operated from a high or wide open position of 11,000 cu ft of gas per hr to a low of 2,500 cu ft of gas per hr and never in an on and off position.

The operator, who also loads the furnace, is stationed where the pyrometer is in sight at all times and adjacent to the loading door is the main gas throttle valve, from which the operator can govern the fuel input.

The billets are pushed through the furnace automatically. They are loaded in the furnace by the operator and the cycle of the pusher is controlled by means of a time clock. Various time cycles are set up for various cross sections and weights of stock. This constant movement of steel through the furnace is a definite factor in heating by providing ample time to thoroughly heat each piece.

CO_2 recorders are used in setting up the proper atmospheres and normal operating conditions will vary from 10.2 to 11 per cent CO_2 while ultimate CO_2 from the gas used is 11.79 per cent.

Heat input over a period of one month averages 2,652,000 Btu per ton with operations consisting of 16 hr of heating, holding heat for delays and a light up each day. Test runs of eight hours reveal that 1,852,240 Btu are required per ton of steel heated.

In burning liquid fuels the simplest method of control consisted of inter-connecting the oil valve with the air valve. A satisfactory furnace atmosphere does not depend upon the oil pressure and air pressure, but also upon the viscosity of the oil. The latter varies considerably with the temperature; therefore, it is evident that proper atmosphere can only be obtained if oil pressure and oil temperature are kept absolutely constant.

An attempt will be made to describe a modern installation of a recirculating system of feeding hot oil at a constant temperature and pressure to all the burners of a group of furnaces.

Oil is pumped through a controlled heater, then through oil lines feeding the burners. A check valve is placed in the main line beyond the last burner to maintain constant pressure. The oil in the return line is sucked back to the pump and the cycle is again repeated.

A small circulating line connects the burner with the main feed lines and the return line. Thus, hot oil under constant pressure is supplied to the burner, and surplus oil passes through the head of the burner flowing in to the return line of the system.

Make up oil is drawn in from a supply line through a low pressure regulator. The pump supplies approximately three times as much oil as can be consumed.

The oil burners on this type of furnace are proportioning in that a constant air-oil ratio is always maintained. Any type of atmosphere can be had and again in forging practice these furnaces produce a uniform heated piece of stock with scale that is readily freed from the forging. CO_2 of 12.5 to 13.5 per cent can be maintained throughout the full range of operation.

All burners of each zone are operated together through linkage operated by a proportioning motor which in turn is operated from a recording controller.

E. C. McDonald: Mr. Bloom apparently advocates raising the roof and shortening the combustion chamber. I would like him to tell me what he considers a good Btu per hour input figure per cubic foot of combustion chamber volume.

F. S. Bloom: The particular item Mr. McDonald refers to here is that shown in Figure 7. With this furnace, we recommend a high combustion chamber at the furnace discharge, with a low roof at the charging end. The first assumption we must make to calculate Btu release is what constitutes the combustion chamber. We all know that fuel does not continue to burn beyond a given distance from the burners. We also know that every furnace has a given limit to the amount of fuel which actually can be burned. If we go beyond this limit our combustion becomes worse and the heating capacity of the furnace decreases.

Once we have determined the actual combustion chamber volume, we design our fuel capacity on the basis of approximately 25,000 Btu per cubic foot per hour. This factor of Btu release is not an absolute

actor for you can realize that it will change with type of burner, fuel, and method of application.

We do know that this combustion volume is an important calculation. Over the past five years, we have changed the combustion volume on numerous existing furnaces and in every case the reduction in fuel and increase in tonnage had been more than could be substantiated by other changes made, such as burner replacements.

A. J. FISHER: I would like to comment on Mr. Gumaer's remark about whether or not it is desirable to cut down the flame to maintain even heat distribution. We have noticed that problem many times in the operation of some of our furnaces, and have tried to maintain maximum fuel input at all times by dampering the furnaces periodically.

I would like to recall to you the firing of four of our large plate mill furnaces on oil. These furnaces have a flame temperature of approximately 3100 F. They are reversed in three to five minute cycles, and when the furnace reaches an initial temperature of 2500 F, the furnace is automatically dampered until a temperature of 2450 F is reached. Then maximum fuel input is turned on until the furnace reaches 2500 F again, etc.

This method gives good heat distribution by maximum firing, and does not get into the unequal heat distributions of low firing.

J. W. PERCY: I would like to comment on one of the illustrations in Mr. Bloom's paper. Referring to the one in which he shows slab temperatures in a triple fired slab heating furnace, I should like to know if these data are theoretical or actual. We recently have been carrying out some tests on a similar furnace, and our curves are not at all like Mr. Bloom's.

F. S. BLOOM: This curve can be most anything. You are bound to have in your soaking zone a uniform temperature. When you get in the heating zone, that curve can be right or wrong. The factor we have not shown is time. The relation of furnace temperature to steel temperature in the main heating zone is a variable depending on how long the steel is to remain in this zone. This curve is an illustration of a principle for correct heating. It is not data from any actual test. Test such as you have conducted should be very beneficial for determining furnace improvement.

O. LUTHERER: I wonder whether Mr. Bloom would be kind enough to tell us something about the influence of hot air on the production of luminous flames.

F. S. BLOOM: We all know that it is much easier to get luminosity in your flame with hot air than cold air.

O. LUTHERER: You also get a reduction in combustion space required by the same token or not?

F. S. BLOOM: I would say that the speed of burning with preheated air and the Btu release per cubic foot, neglecting available heat, is very closely the same.

This question can be misconstrued due to the fact that we do not consider total available heat and likewise flame temperature. I believe that the same volume of gas can be burned per cubic foot of combustion volume with either cold or hot air. Therefore, the heating capacity of a furnace is greater with hot air than with cold air and likewise if the same furnace heating capacity is desired, the combustion volume could be smaller with the hot air than with cold air. Furnace design practice does not follow this type of calculation for in most cases combustion volumes with hot air are greater than for cold air. This comes largely from experience with refractory failures, and high temperature flames coming in contact with the steel being heated.

O. LUTHERER: That is contrary to premixing burners.

F. S. BLOOM: I don't know. I never tried to premix hot air with any gas. I think it would be dangerous.

O. LUTHERER: The natural tendency would be to get much faster combustion with preheated air unless the increase in the viscosity of the hot air resulted in poorer mixing between air and gas in the furnace.

F. S. BLOOM: Isn't there another problem there? When you get into preheated air, your weight of oxygen per cubic foot of preheated air is much different from that of cold air. Consequently, the fuel must hunt around for the oxygen more with preheated air than with cold air. I think that is the answer.

With all our experience with high preheated air, I haven't seen any results that tend to indicate that we can burn more fuel with preheated air than we can with cold air. If anything, we can burn more fuel with cold air than preheated air. For general steel mill furnace application, a burner to use hot air should delay combustion so that too high flame temperatures are not obtained.

SPECIAL *Electrical Applications in the* STEEL INDUSTRY

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▲ THE remarkable progress of the steel industry during the past decade becomes vividly real to the observer when his thoughts revert over that relatively short period. Progress is in evidence in the new principles in steel making as well as in new developments and refinements in apparatus. But advancements are ultimately apparent in the lower costs, the higher production, the new products, and the better quality of steels.

In the steel mill there been changes in the apparatus which, for example, is of direct concern to the mill operating men. Where formerly one would see operators handling the material with gloved hands, with tongs, or with bars, one now will frequently see the operators at electric control stations remote from the material being processed. Control pulpits, control stations, or control desks have placed the men where they have, in many cases, better control of the processing than if they were touching the steel itself. The mill operator has often virtually a "desk job" as he operates the control switches and push buttons.

Where formerly a close scrutiny of the steel was the one assurance that the mill was operating satisfactorily, instruments and meters now give the operators an immediate indication of the steel's condition as well as that of the apparatus in use. Electric indicating instruments show what "is happening", while electric recording meters give a history of what "is happening or has happened". In fact, an intelligent understanding of meter indications will point out what "will happen". Thus, where formerly steel making was an art dependent on the operator's senses, it is now rapidly becoming more and more a scientific art, dependent on the instruments located at the control stations or on instrument panels and cabinets. Temperature meters, motor load indicating meters, speed indicating meters, thickness gauges, pressure gauges, and furnace or combustion meters are just a few of the instruments which the mill operator uses, much as he does his own pocket watch.

This paper will briefly review some of the special instruments and principles of control which have been developed. A few of the instruments are not entirely new, but they will be described only because they are not well known in the steel industry.

INSTRUMENTS

Many of the electrical instruments herein described operate on the principle of the variable air gap transformer and the Wheatstone bridge. It may be well, then, to review the principles upon which the instruments are constructed.

The variable air gap transformer consists essentially of a U-shaped core with an exciting or primary winding wound on one or both legs, a secondary winding on one or both legs, and a movable armature across the ends of the legs to form a return path for the magnetic flux. Referring to Figure 1, the flux in the yoke varies in proportion to the air gap between the armature and the ends of the legs or yoke. Because an alternating voltage is applied to the primary, the secondary voltage varies with the flux, and hence, with the air gap. Since the permeability of the steel yoke is several thousand times that of the air gap, a very small change in the air gap means a tremendous change in the flux, and therefore, the secondary voltage. Thus, the air gap principle is extremely accurate, and is used in the electro-limit gauge for giving a continuous indication of strip thickness while the strip is in motion. The principle is also employed in the tensiometer which measures the tension in a steel strip, and which has more recently been applied in wire drawing machines for indicating wire tensions.

Just as all electric circuits have been jokingly simplified by referring to the complex ones as "nothing but a group of circuit constants in series-parallel combinations", so all circuits may often be broken down into one or more Wheatstone bridges. This humble device

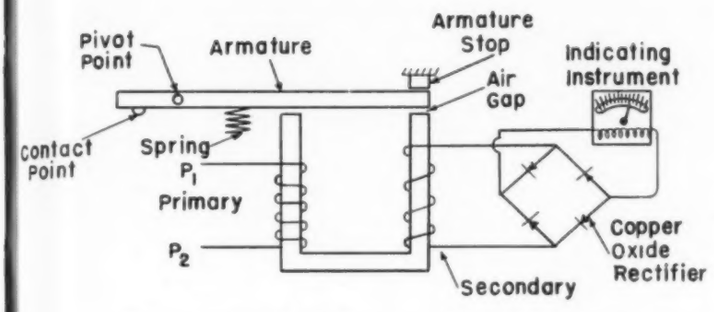


Figure 1—Simplified diagram of variable air gap transformer.

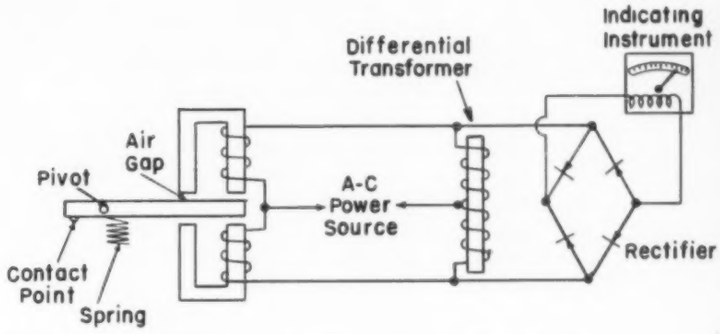


Figure 2—Variable air gap transformer applied to wheatstone bridge circuit.

enables us to broaden the range of application of the variable air gap transformer. Figure 2 shows the Wheatstone bridge with three legs, each consisting of any of the three principle circuit parameters (resistance, capacitance, inductance) of known value. The fourth leg is usually of unknown value, or its electrical magnitude is varied. If potential is applied at diagonally opposite points of known potential difference, and the unknown value is, for instance, equal to the values of the other three legs, no potential difference exists between the other two diagonally opposite points. However, if the unknown value is greater or less than the known values of the other three legs, the potential difference between the other diagonally opposite points will increase or decrease accordingly. This is a most accurate and sensitive method of measuring electrical quantities.

Figure 2 is the simplified circuit of the electro-limit gauge, utilizing both the Wheatstone bridge circuit and the air gap transformer device. Two of the legs of the Wheatstone bridge are comprised of coils, one above and one below the movable armature. These coils are wound around the U-shaped yokes, and their voltage output is dependent upon the air gap between the yokes and the movable armature. If the armature moves up, the voltage in the top coil increases and decreases in the lower coil. The other two legs are of known value and it will be noted that the alternating current power is applied at a point between the air gap coils and the mid-point of the other two legs. The indication is obtained from the other two diagonally opposite points. Variation in the thickness of the strip being measured will produce up and down deflections on the armature.

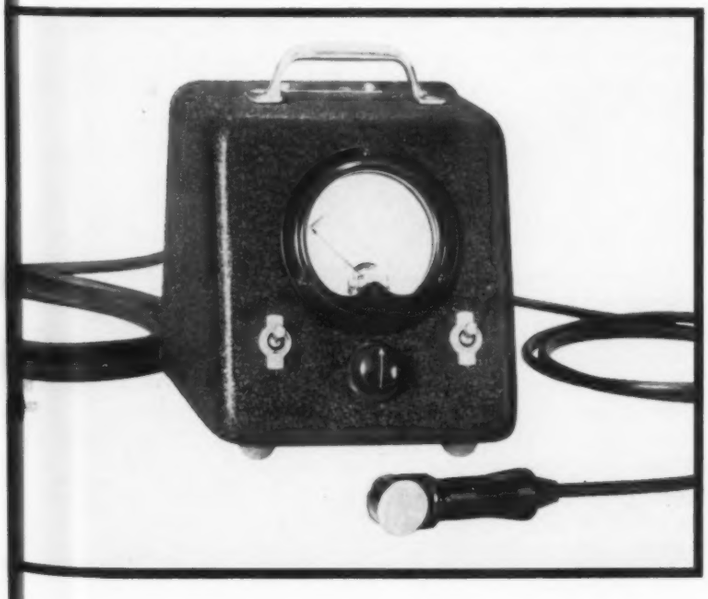
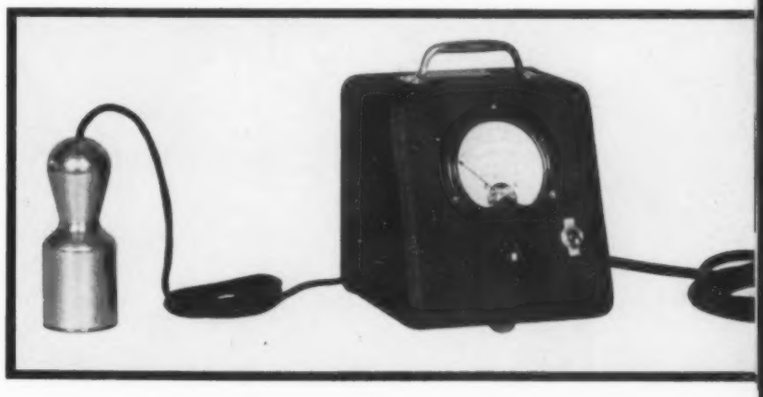


Figure 3—Gauge for measuring thickness of non-magnetic material when only one side of material is accessible.

Figure 4—Gauge for measuring thickness of magnetic material from one side of sheet.



The ultimate effect will be a deflection of the thickness gauge instrument pointer. The scale on the meter is calibrated in units of thickness.

THICKNESS GAUGE FOR MEASURING NON-MAGNETIC MATERIALS

The photograph in Figure 3 shows a gauge, based on the same principle as the electric gauge just explained, for measuring the thickness of non-magnetic sheets, or coatings placed on iron and steel. In this case three of the bridge legs are located in the instrument case, and the fourth is located in the small handle shown at the bottom of the photograph. It will be noted that there are two parallel discs spaced approximately ¾ in. from each other on the handle. Each of these discs is connected to the ends of a U-shaped core, and, when the discs are pressed on a non-magnetic material backed by a magnetic material, the flux obtained is in proportion to the thickness of the non-magnetic material. This thickness of non-magnetic material is indicated directly on the indicating instrument. The gauge is being widely used in the industry for measuring enamel coatings and the like. A modification of this gauge is being used in the aluminum industry. The instrument has two scales, one reading from 0 to 8 mils, and the other from 5 to 100 mils. Modifications of the gauge can be made with different scales. As a matter of fact, we have done some work in reading the thickness of the tin coating on tin plate. Here, the non-magnetic coating is in the order of sixty-millionths of an inch, and although the gauge can be made sensitive enough to read this, great care must be taken in placing the discs properly on the surface. A slight film obtained from moisture on the hand, a pencil mark, or the like, is greater than the thickness being measured.

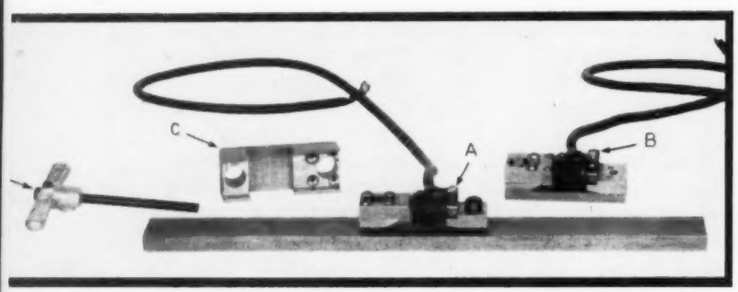
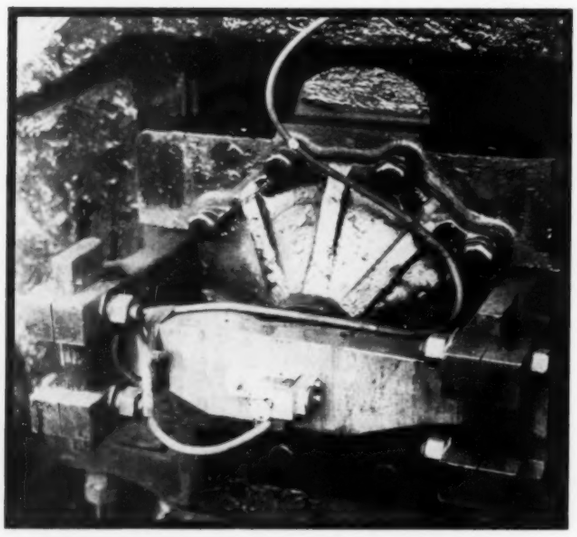


Figure 5—Strain measuring gauge. *A*—Strain gauge head mounted on test bar. *B*—Balancing unit. *C*—Attaching fixture.

Figure 6—Electromagnetic strain gauge and weigh bar applied to end of locomotive axle.



SHEET STEEL GAUGE

This gauge operates on the principle of the air gap transformer gauge, except that the magnetic steel closes the air gap entirely, and the flux is dependent upon the thickness of the steel. The cylinder shown in Figure 4 consists of an inside core with coil forming one leg of a transformer, and an outside cylinder forming the other leg. The exciting winding on the inside core saturates the steel being measured, and the flux required to saturate the steel is a measure of the thickness.

This gauge has been made with two scales: one scale measuring from 20 to 45 mils for ordinary low carbon steel, and the other scale for 10 to 25 mils for sheet steel of medium silicon content.

The strong magnetic attraction of the gauge head assures intimate contact with the sheets. Thin coatings of enamel or surface corrosion do not appreciably affect the readings on thin sheets. The variation in permeability of the steel being measured affects the accuracy somewhat, but the accuracy of the indication is approximately 5 per cent of full scale.

The advantages of this gauge are that uniformity of material thickness can be quickly determined. It is believed that this gauge will have considerable use in skin pass operations for determining the convexity and concavity of strip before it is skin passed. As is well known, if the strip is concave, there is a tendency for the strip to pinch and ruin the rolls. However, if the strip is convex, there is no tendency to pinch.

STRAIN GAUGE

The strain gauge is a variation of the electric gauge designed for measuring mechanical strains. The photograph in Figure 5 shows the two legs of the bridge circuit A and B. A is mounted on the member under test, and is balanced against B before the member is subjected to mechanical forces so that the indicating instrument shows zero. B can be remote from the member being tested. When the member is subjected to mechanical strain, A's air gap changes with respect to B's so that the bridge circuit becomes unbalanced and this unbalance is shown on the indicating instrument. Auxiliary equipment can be furnished with the gauge in line with

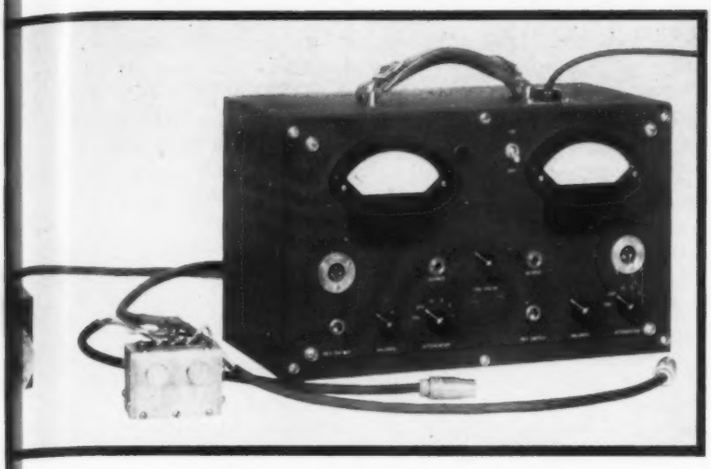


Figure 7—Tool pressure gauge, showing (*left to right*) tool holder, balancing unit and indicating unit.

the type of strain to be recorded. For example, where strain measurements are required on a member which is subjected to sharp blows, high frequency equipment, consisting of a 2000 cycle oscillator power unit and oscillograph, would be required to follow the rapid changes in stress in the test member.

As an interesting sidelight, a large railroad system purchased a number of these strain gauges for use in studying strains in track and bridge structure. The studies were made because of the innovation of new and heavy high speed engines traveling over the track and bridges. It was thought that many of the bridges would have to be rebuilt. However, after performing the tests with this equipment, it was found that by making local reinforcements of the structure, the bridges would not have to be rebuilt. Estimates showed that about $15,000,000 was saved by the railroad.

Another test was made on the forces acting on the axles and surrounding members of the engine. Strain gauges were applied to the ends of the axles, as shown in Figure 6. The engine was run at 115 miles per hour down a straight stretch, and then around a right hand curve. Oscillograph records were made of this, and from a study of these records accurate information toward improving the design of the tracks was obtained.

To our knowledge this equipment has not yet been greatly utilized in the steel industry, but due to the tremendous forces and rough treatment obtained in mill equipment, it would appear that this equipment could be used to great advantage in determining unknown forces.

ELECTRIC TOOL PRESSURE GAUGE
ELECTRIC PRESSURE GAUGES

The tool pressure gauge shown in the accompanying photograph, Figure 7, was developed to measure cutting tool pressures independently and simultaneously in two right angle directions. When installed on a lathe, for example, the equipment will indicate the downward pressure for the cutting tool, as well as the longitudinal pressure.

Referring to the photograph, the cutting tool holder is shown at the left. It consists basically of a cylindrical bar which is pinned in a mounting block. The bar is provided on the front end with a square hole to receive the tool bit. When pressure is applied to the tool bit, the cylindrical bar deflects elastically a slight amount—not exceeding 0.002 in. for the maximum pressure of the range for which it is designed.

The cylindrical bar carrying the tool bit is surrounded by a tubular member which is fastened rigidly to the mounting block. This tubular member does not participate in the tool holder deflection in that no forces are applied to it. When the tool bit carrying bar deflects elastically, the gap between the tubular member and the bar changes in proportion to the tool pressure applied. Electric gauge pick-up elements are installed on the tubular member to measure the change of gap. One of these elements is attached to the top to measure the vertical beam deflection, and another one is arranged in a horizontal axis to measure the horizontal beam deflection. These electric gauge pick-up elements form bridge circuits with the balancing units, and the instrument system indicates the amount of bridge unbalance.

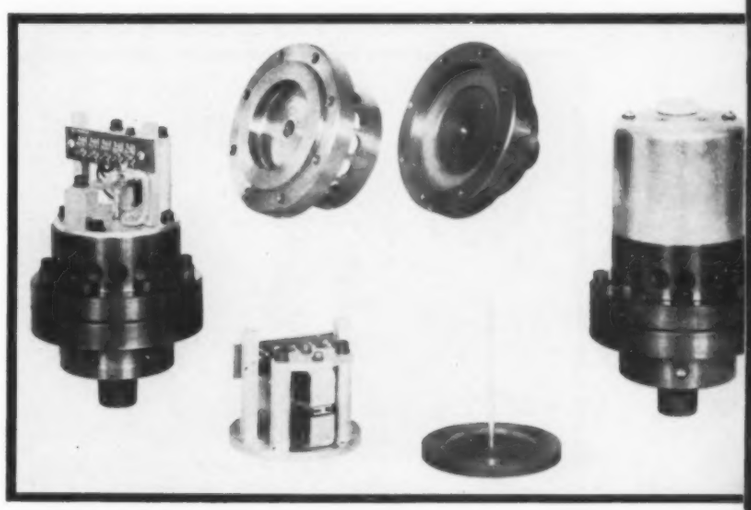
The tool holder shown is for a $\frac{3}{8}$ in. x $\frac{3}{8}$ in. tool bit, and it is designed for a maximum pressure of 500 lb. For higher tool pressure and larger tool bits, a larger pressure responsive tool holder must be used. This, however, does not change the basic principle in any way.

The indicating unit contains a rectifier d-c power unit, a 2000 cycle oscillator, and two highly stabilized amplifier channels. The two pressure indicating instruments are connected in the output of the two amplifier channels. The accuracy of such an instrument is approximately 5 per cent of full scale.

Here again, it is believed that this gauge will find use in the steel industry, solving some of the perplexing problems that now exist.

The accompanying photograph shows two types of

Figure 8—Diaphragm type pressure gauge. Complete unit at right; with cover removed at left; and disassembled, center.



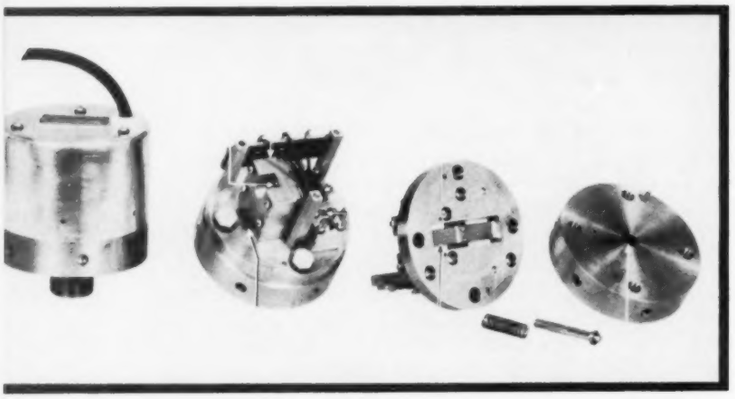


Figure 9—Piston type pressure gauge. Complete assembly at left; disassembled to the right.

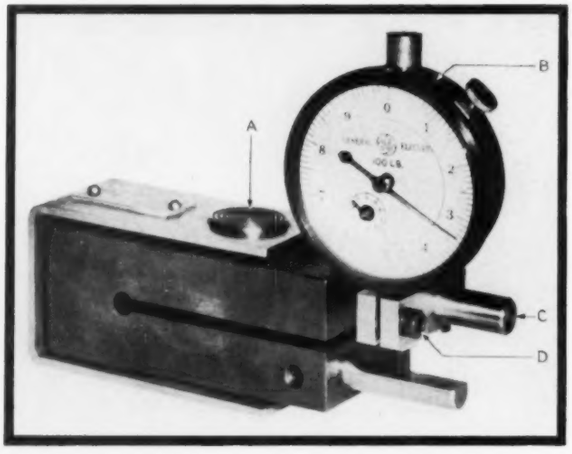
pressure gauges: one of the diaphram type, Figure 8, for measuring low pressure, say up to 1000 psi, and the other of the piston type, Figure 9, pressure gauge for measuring up to 15,000 psi. Here again, these pressure gauges work on the principle of the electric gauge. The diaphram or piston operates an air gap transformer, and the pressure is indicated directly on the instrument. This is used for measuring gas, liquid, or steam pressures.

ELECTRODE PRESSURE GAUGE

The gauge shown in Figure 10 is designed to measure the pressure between the electrodes of resistance welding machines. It may also be used to check the pressures between electrodes on spot, line, and projection welders. This is purely a mechanical gauge, and is not electric in any sense of the word.

It consists of a calibrated steel yoke and a dial indicator calibrated to read in pounds. This indicator is connected by means of a simple linkage to the steel yoke, so that when pressure is applied to the yoke its deflection is measured by the dial indicator. The dial indicator has a main scale of uniform calibration, which reads pounds within the range of zero to 1000. A small scale reads pressures of zero to 4500 lb in 1000 lb increments. One revolution of the large hand on the large scale registers 1000 lb on the small scale.

Figure 10—Mechanical type electrode pressure gauge.



PHOTOELECTRIC WIDTH GAUGE

The photoelectric width gauge is an equipment designed essentially for a continuous measurement of the widths of moving webs or strips of material, without contacting the material. Figures 11 and 12 show the front, or the delivery side, of the width gauge.

The strip of material is made to pass between two detector units, one on each side of the strip. Each of

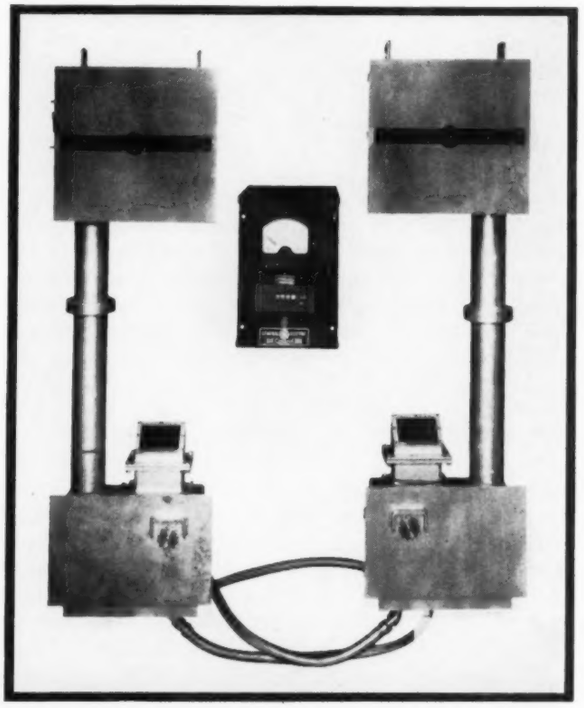


Figure 11—Front view of both scanning units of photoelectric width gauge for hot strip mill.

these detector units has a standard light source, lens system, and a mirror for producing a beam of light which is projected from above to the edge of the strip, where it is partially interrupted. The portion of the beam which is not interrupted is focused by a lens system on a photoelectric tube located below the strip, and this light sensitive device allows a flow of electrical current proportional to the amount of light falling upon

it. By virtue of the fact that the mirror of the optical system is mounted on the movable element of a D'Arsonval type electrical instrument, rotation of the instrument causes the beam of light which is projected from the source to the mirror to sweep angularly in a plane vertical to the plane of the material, and at right angles to its direction of travel. Thus, the movement of the galvanometer-mounted mirror is capable of projecting a beam of light on the edge of the material, even though its side register should shift within allowable limits.

As the edge moves, the beam will follow the edge in order to maintain the light balance. Thus, because of an accurate relationship between beam position and instrument current, current is a measurement of the position of the edge of the material. However, to measure width, a right-hand detector is required to determine the position in space of the right-hand edge and the currents of both left and right detectors are totalized on one indicating instrument measuring width. An increasing current in the totalizing instrument shows an increase in width and a reduction in current shows a reduction in width. It can be seen from this that a shifting in side register with constant width of material simply adds current to the detector on one side and subtracts current from the detector on the other side, with a net result of no change on the indicating instrument.

The accuracy of indications in width are somewhat dependent upon the position of side register of the web within the zone of side register for which the equipment is designed, as well as the magnitude of change in width. Considering the principal optical axis of the lens system which projects the beam across the edge of the web as the correct side register position, an accuracy of plus or minus $\frac{1}{32}$ in. can be expected within a zone of $\frac{1}{2}$ in. shift in side register from this point or $\frac{1}{2}$ in. change in total width dimension. For a change in side register up to $\frac{3}{4}$ in. on either side of the principal optical axis, an accuracy of plus or minus $\frac{1}{16}$ in. can be expected. This accuracy also would apply to a net change in width dimension of $\frac{3}{4}$ in.

These values are actual and hence become an increasing percentage of error as the normal width of the material being measured decreases.

A maximum shift of plus or minus $\frac{3}{4}$ in. in side register measured from the principal optical axis seems to be a practical design limit at present. Widths of material down to 6 in. wide can be measured and, by staggering the detector heads, it may be possible to reduce this value somewhat.

The web should be practically flutter-free at the point of measuring, but a motion of a total of 2 in. could be tolerated at the elevation at which the web intercepts the light beam.

The speed of response of the system is limited only by the damping of the electrical instruments and is in the order of $\frac{1}{2}$ second for a full scale change of indication.

Care must be exercised in preventing excessive amounts of vibration from being transmitted to the equipment. By excessive amounts of vibration is meant a value sufficient to cause an appreciable movement of the galvanometer element mounting the mirror, or to cause mechanical distortion of the optical system.

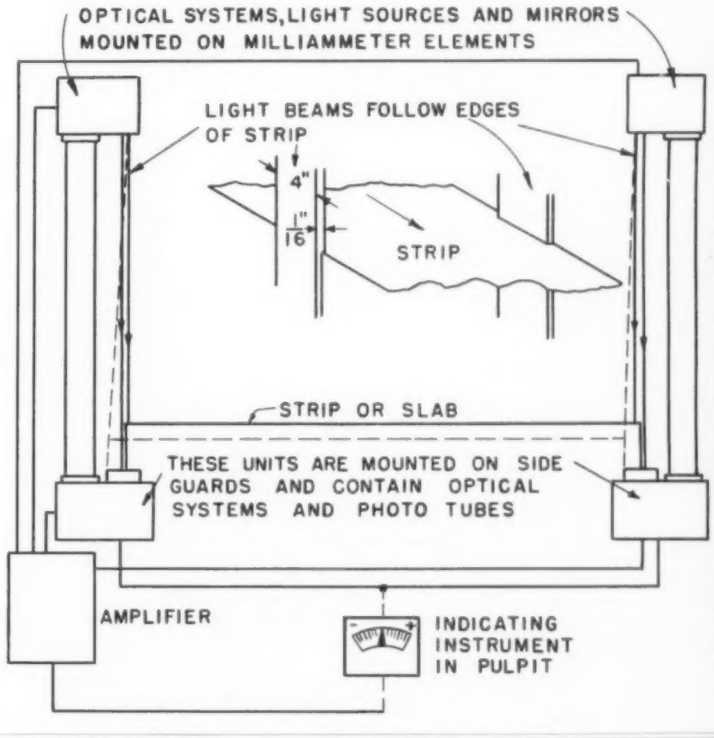
The ambient conditions under which the equipment must operate deserve careful consideration. Any atmospheric contamination, such as dust, scale, lint, dripping water, smoke and steam, are all either opaque to light or cause dispersion, and hence will affect any system responsive to the quantity of light transmitted through a space in which this contamination exists. This is not be be confused with the normal amount of air-borne substances which accumulate on lens surfaces and can periodically be cleaned to maintain successful operation. Exposure to radiant heat in such an amount as to elevate the temperature of the equipment above 90 C total temperature can only be treated as a special consideration.

This gauge was designed primarily for the indication of the width of hot strip, and, although it is sound in principle and in operation, it does not appear to be practical for this particular use because it is almost impossible to eliminate the hot scale which coats the lens. There may be other applications for this device than that of measuring hot strip. Experiments are being continued in the use of a gauge of this nature for measuring hot strip, and we are hopeful that we will be able to conquer this problem in the near future.

STRIP GRINDING AND POLISHING MACHINE

With metallic strip being rolled, by the continuous process, to a greater and greater extent, it is quite natural that the strip should be processed, where possible, while in the coiled form. The strip grinding

Figure 12—Sketch showing positions of light beams on photoelectric width gauge.


OPTICAL SYSTEMS, LIGHT SOURCES AND MIRRORS MOUNTED ON MILLIAMMETER ELEMENTS
LIGHT BEAMS FOLLOW EDGES OF STRIP
4"
1/16"
STRIP
STRIP OR SLAB
THESE UNITS ARE MOUNTED ON SIDE GUARDS AND CONTAIN OPTICAL SYSTEMS AND PHOTO TUBES
AMPLIFIER
INDICATING INSTRUMENT IN PULPIT

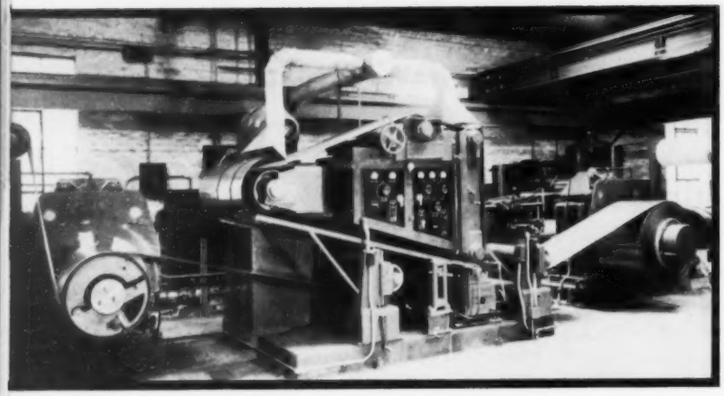


Figure 13—View showing strip grinding and polishing machine with tension reels.

machine utilizes the relative motion between a moving strip and a polishing belt to produce a desired finish on one or both sides of a continuous strip. Stainless steel is, for example, polished in the machine as the coils of steel are unwound from a pay-off reel and rewound on a tension reel, as shown in Figure 13.

Figure 14 shows in schematic form a circuit which is being used for uncoiling the strip and then recoiling it after polishing. The principal function of the control is to operate the reels so that the strip is held under constant tension, as it moves at constant speed under the polishing belt. In Figure 14 the right wind (RW) contactors are closed and the strip is shown passing from left to right. After having passed the strip to the right, the left wind (LW) contactors are closed and the right wind contactors are opened. So the process can now be reversed, with the strip passing from right to left.

If we consider the strip passing from left to right, it is obvious that the left reel must speed up as it pays off the strip, while the right reel must slow down as the strip builds up on the reel drum. During this entire process, the strip is automatically held at an essentially constant linear speed and also at a constant tension, the value of which is determined by the tension rheostat setting. Here we have a paradox of both reel motors continuously changing in speed, yet the strip remains at a practically constant speed and tension.

The main part of the tension and speed control is in the tension reel motor circuits. When winding from left to right, the armature of an amplidyne exciter is connected across the field circuit of the left reel motor. The control field of the amplidyne carries a current proportional to the algebraic sum of the voltage drops across the fixed resistors in each motor armature circuit. Thus, as the coil is unwound and rewound, the field of the left motor is strengthened, and that of the right motor is weakened.

Acceleration or deceleration of the strip is accomplished by means of voltage control on the main generator. The booster generator is used in the pay off reel circuit to maintain the strip under tension, even when the strip is at rest.

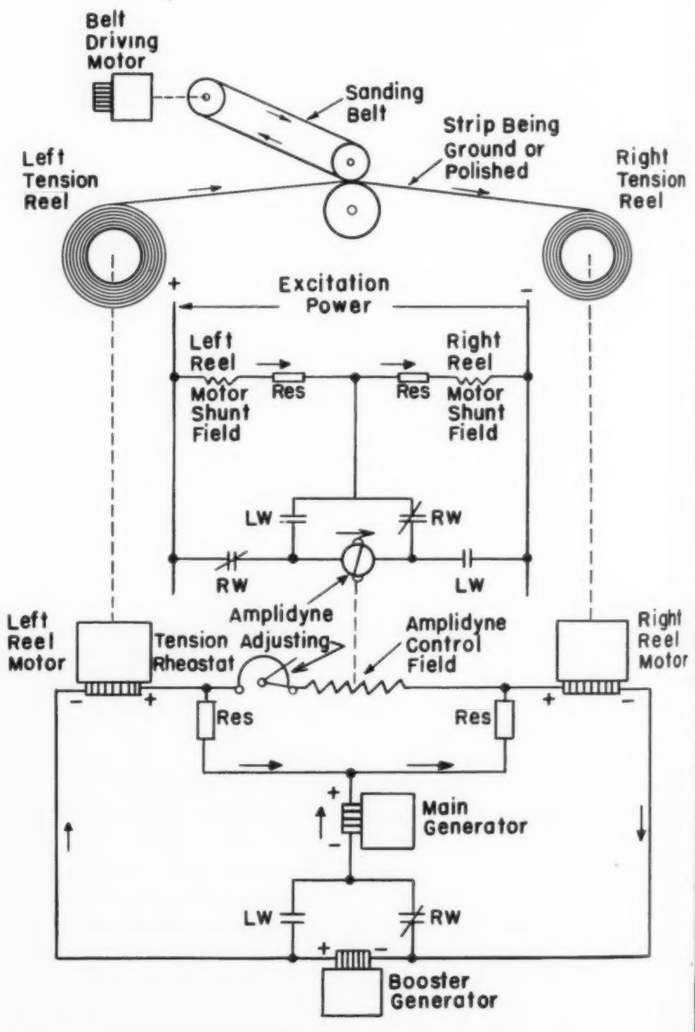
A few of the advantages in such a strip grinder control scheme are:

(a) No cumbersome rider roll rheostats on the coils are necessary to compensate for the changing coil diameters.

(b) The variable voltage method enables a completely regenerative power control scheme to be used at all times. The pay off reel motor will be acting as a generator, while the winding reel motor is being motored. Consequently the main generator capacity need be but a fraction of the motor ratings. Such savings in generator capacity are further increased by a low net electric energy consumption.

(c) Tension control, speed control, stalled tension, and simplicity in operation are all benefits derived from this amplidyne application in conjunction with a variable voltage control. In one application a 7:1 range in speed, and a 40:1 range in tension is required.

Figure 14—Simplified schematic diagram of fundamental circuits for strip grinder (set for winding on to right reel).



ELECTRIC TIE ON HOT MILL FLYING SHEARS

In modern continuous hot strip mills, the steel strip is either coiled, while hot, or it is cut into sheets as the strip emerges from the last rolling stand of the tandem finishing mill. In the latter case, such strip is literally sheared "on the fly". Hence, the shear used is aptly termed a "flying shear". Figures 15 and 16 show two different views of a shear.

The flying shear on hot strip mills is invariably of the drum type, in order that it may cut the strip while the strip is moving at speeds in the neighborhood of 2000 fpm. As shown in Figure 17, the drums of the shear contain knives which shear the strip as the strip passes through the shear, a cut being made as the knives of opposite drums come together.

Usually the shear has its greatest application in cutting the strip into sheets of uniform lengths of 15 to 30 feet. It may also be used to crop the jagged front end of the strip, or perhaps, the tail end of the same strip. In any case, the shear must be rapidly accelerated from rest so that the linear speed of the knives is at least equal to that of the strip. Amplidyne control of the shear generator fields has done much to give the shear driving motors that necessary "snap" from rest to top speed or from a running condition to a stop with a greatly simplified means of control. Figure 17, however, does not show this part of the control. Instead, its purpose is to demonstrate the speed control system used on the flying shear, after the shear is up to running speed.

The length of each sheet cut by the shear is proportional to the average strip speed through the shear and inversely proportional to the average linear speed of the knives. The strip speed is determined by the delivery speed of the last stand of the mill. The knife speed is determined by the speed of the shear driving motor. In the past, some variable-ratio mechanical tie was used between the last stand and the shear. This took the form of either a gear unit, the speed ratio of which could be changed, or a variable displacement type of hydraulic motor and generator drive. By means of the electric tie, involving the amplidyne and a vacuum tube speed regulator, the initial cost and maintenance requirements on all types of mechanical ties can be eliminated.

In Figure 17 the coarse speed tie is obtained by comparing the voltage on the shear motor armature with that of a tachometer generator geared to the driving motor of the last stand. The differential voltage, between the shear motor armature and the stand tachometer generator, is applied to an amplidyne control field. The amplidyne excites the shear generator to a voltage such that the speed of the shear motor will approximately "match" that of the finishing stand. It should be noted that speed control of the shear motor is by means of armature voltage alone. This expedient not only is more flexible than motor shunt field control, but it is also desirable because of the great speed range through which the shear operates. In order that the shear may cut sheets from, say 15 to 30 feet in length, the shear must operate through a 2:1 speed range, for a given strip speed. Usually the last stand will have a 2:1 speed range by armature voltage control of the

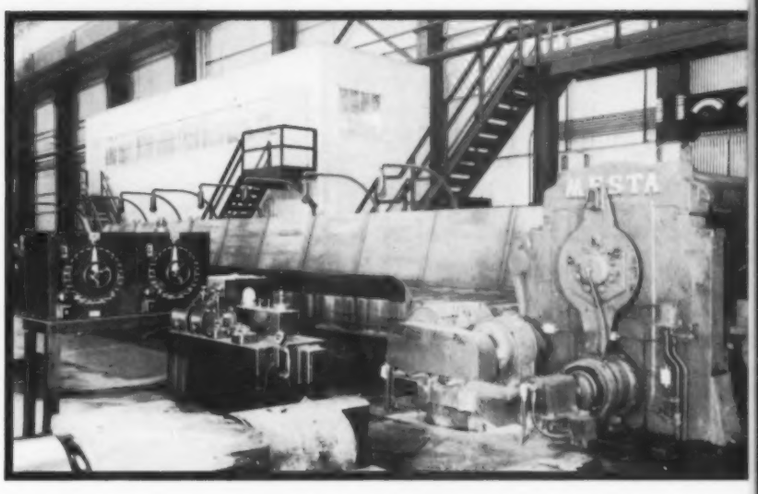


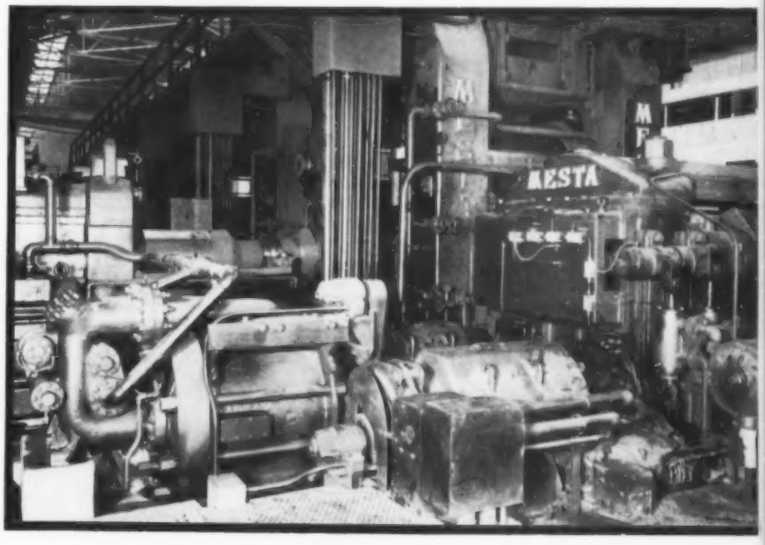
Figure 15—Flying shear on continuous hot strip mill, viewed from operator's side of mill.

stand driving motor, and a 2:1 range by shunt field current change. The over-all speed range of the shear driving motor must then be 8:1.

The coarse speed tie is "coarse" for two reasons. Firstly, the shear motor armature voltage is not strictly a measure of shear speed. Secondly, the shear is made to operate at a speed of 10 to 15 per cent above "synchronous speed" if the vacuum tube regulator is out of service. By synchronous speed is meant that shear speed which will produce the desired length of cut.

When the vacuum tube regulator is in service, it will "pull" the shear speed from above synchronous speed to a synchronous speed corresponding to the cut-length rheostat setting. In short, then, the coarse tie tends to "push" the shear speed through synchronism while the

Figure 16—View showing hot strip flying shear from driving side.



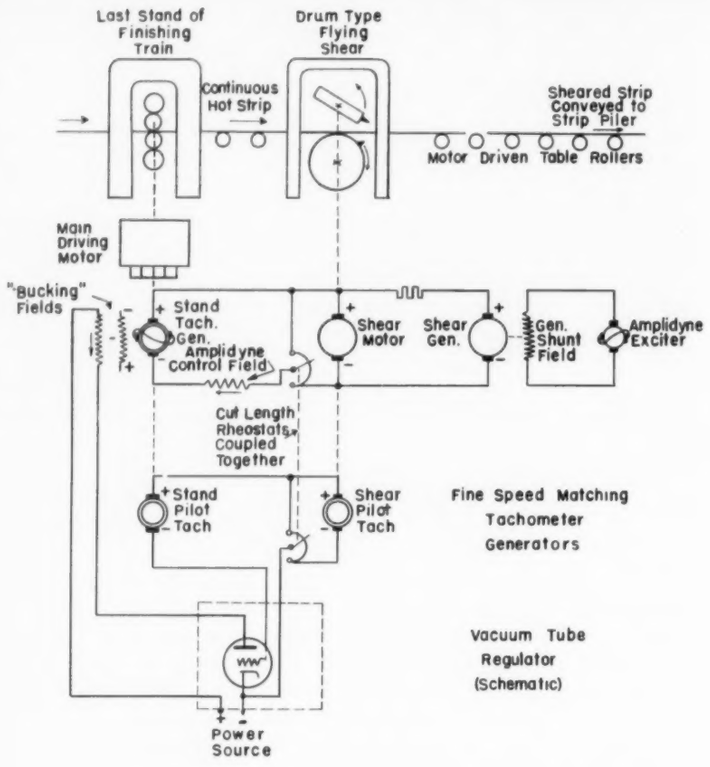


Figure 17—Sketch showing schematic arrangement of control for hot strip flying shear.

regulator prevents the shear from going faster than synchronous speed.

"Fine" speed control indication is obtained from the difference in voltage between the stand pilot tachometer and the shear pilot tachometer. The vacuum tube regulator tends to hold "zero volts" between the two pilot tachometers by recalibrating the stand tachometer generator; that is, by lowering the net field strength of the stand tachometer generator. When the input voltage to the regular is "zero", the shear will be at synchronous speed.

The regulator is a two stage amplifier containing tubes of the type used in radio receivers. Therefore the regulator is a dependable and easily maintained piece of apparatus. However, should a tube fail while the shear is in operation, the failure will not cause the shear to stop and, perhaps, produce a serious "cobbling" of the hot strip. Instead the shear will continue to operate, but at a speed slightly above synchronous. In fact. by sacrificing accuracy of cut length, the shear may be operated without the tube regulator.

But what are the advantages of the electric tie over other means of regulating the shear speed? Some of the benefits from the electric tie are:

(a) The shear will require less mechanical equipment, and hence, a lesser amount of mechanical maintenance, with a slight increase in the amount of electric control apparatus.

Figure 18—Simplified schematic diagram of reversing cold strip mill (set for rolling from left to right).

(b) The length-of-cut rheostat is calibrated in sheet lengths, so that cut order changes may be quickly made by turning a single rheostat. Changes in the calibration due to changes in work roll diameters of the "feed" stand can also be quickly compensated for on a roll diameter compensating rheostat.

(c) Should the last stand be "dummied", due to a breakdown for example, the shear may still be operated, using the next to the last stand as the "feed" device. Such an arrangement is accomplished by a transfer switch which transfers the control from the tachometer generators of the last stand to those of the preceding stand.

Table I shows how favorably the electric tie compares with the oil gear tie as far as accuracy of cutting is concerned. In analyzing these tables, it should be remembered that even with a "solid tie" between the last stand and the shear, there will still be a discrepancy between sheet lengths of the same slab. This follows from the fact that the rate of feed to the shear is not constant (due to waves in the strip, or the like) even when the last stand is delivering strip at a constant rate. The tables are from data taken at random on a hot strip mill which now has the electric tie in place of the former oil gear tie.

REVERSING COLD STRIP MILL CONTROL

The control of the winding and unwinding reels of a reversing mill differs from that on a reversing strip grinder in that the reversing mill stand is the "pacesetter". It is necessary for the reversing mill reels to hold tension only, since the entry and delivery speeds of the strip are determined by the per cent reduction and the speed of the mill motor. The reversing mill reels are, however, like those on the strip grinder because the unwinding reel motor acts as a generator while the winding reel motor is motoring. Again, in both cases, it is desired to hold a constant strip tension which may be changed by a hand operated rheostat. Usually the reversing mill winding and unwinding reels, unlike those on the grinder, will operate at their own respective values of tension.

Figure 18 is intended for the purpose of showing the method of controlling the reel motor fields by means of an amplidyne in each reel motor circuit. Details, showing means of jogging the motors, starting or stopping circuits, regulator stabilizing circuits, and the like, have been omitted, in order to simplify the diagram.

Before describing the amplidyne control of tension, a brief description of the generator control circuit should be worth while. In Figure 18, the reels and the mill motors are accelerated from rest to a threading or runrung speed by simultaneously raising the voltages on the reel generators and the main generator. The generator exciter excites the shunt fields of the three generators in conjunction with a motor operated rheostat. Assuming the strip is passing through the mill from left to right, so that all right-wind (RW) contactors are closed, (on left wind, all RW contactors will be opened and the LW ones will be closed), the generator field exciter will have its separately excited field strengthened as the motor operated rheostat is "raised". Section A of the rheostat strengthens the main generator field until rated voltage is on the main generator. At the half-way point on the rheostat, sections B and C come into operation. With constant voltage on the main generator, the speed of the mill is further increased by weakening the field of the main motor as section C cuts in resistance. Section B is meanwhile strengthening the reel generator fields so as to further raise the voltages on the reel motors. During this accelerating period, the amplidyne regulator will have been controlling the reel motor fields. The method of control may thus be called the "full field method of acceleration" because the mill motor field will remain at a base-speed setting until the armature voltage is up to rated value.

For many years, tension reels have been made to hold a relatively constant strip tension by varying the strength of the tension reel shunt fields, in order to hold a constant value of armature current. If the armature voltage on the reel motor is constant, and the regulator holds constant armature current, the power input to the motor will be constant. If we assume constant electrical and mechanical losses, the mechanical power from the reel motor will be constant, the power being proportional to strip speed times tension. Finally, for a given strip speed, the tension in the strip will be proportional to armature current. Most current regulators hold tension by utilizing these well known principles of reel motor field control during the winding or unwinding periods. Whether the reel motor is regener-

TABLE I

Oil Gear Tie with Amplidyne Control

Slab No.	Date rolled and sheared	Sheet thickness, in.	Sheet width, in.	No. of sheets per slab	Average sheet length per slab, in	Difference between longest and shortest sheet, in.
1	3/17/39	0.187	73.5	9	170.0	3.0
2	3/17/39	0.128	61.5	12	200.2	3.1
3	3/17/39	0.135	64.3	12	224.2	2.4
4	3/17/39	0.135	61.5	12	245.4	2.2
5	3/17/39	0.135	61.5	12	246.7	1.3
6	3/17/39	0.135	61.5	12	246.6	2.3
7	3/17/39	0.191	49.5	12	292.1	2.0
8	3/17/39	0.191	49.5	10	331.3	1.0
9	3/17/39	0.191	49.5	11	330.4	1.1
10	3/17/39	0.191	49.5	10	330.9	1.7
11	3/17/39	0.191	49.5	5	330.7	1.0

Electric Tie with Amplidyne and Vacuum Tube Regulator Control

1	9/29/40	0.125	61.2	13	297.7	4.3
2	10/ 3/40	0.135	48.3	10	294.0	1.5
3	11/20/40	0.122	37	17	297.1	1.5
4	11/20/40	0.167	37	8	294.0	1.1
5	11/23/40	0.120	37	15	257.3	1.3
6	11/23/40	0.120	37	13	257.5	1.4
7	11/23/40	0.120	37	17	258	1.4
8	12/10/30	0.144	74	11	198.3	2.1
9	12/10/30	0.167	65	10	201.0	2.7
10	12/10/30	0.105	71	11	296.0	2.3

ating or absorbing power, makes no principal difference.

In either reel control shown in Figure 18, the amplidyne will "buck" or "boost" the main excitation voltage. As the strip is unwound from the left reel, the left reel amplidyne will speed up the motor by producing more voltage in the "buck" direction. Similarly, the right reel motor will be slowed down by having its amplidyne produce more voltage in the "boost" direction. The purpose of the reel generator auxiliary fields across their respective amplidynes is two-fold. First, this enables the reels to hold stalled strip tension with the mill at rest. Secondly, the generator auxiliary field will compensate for the reel motor armature circuit resistance times current drop.

Four amplidyne control fields, all on the same axis, are shown for each amplidyne. Sometimes three such fields are used in conjunction with an amplifying exciter, but the diagram illustrates the principles involved in most instances.

The voltage limit field prevents the voltage on the amplidyne from going too much "buck" and causing excessive field weakening of each reel motor.

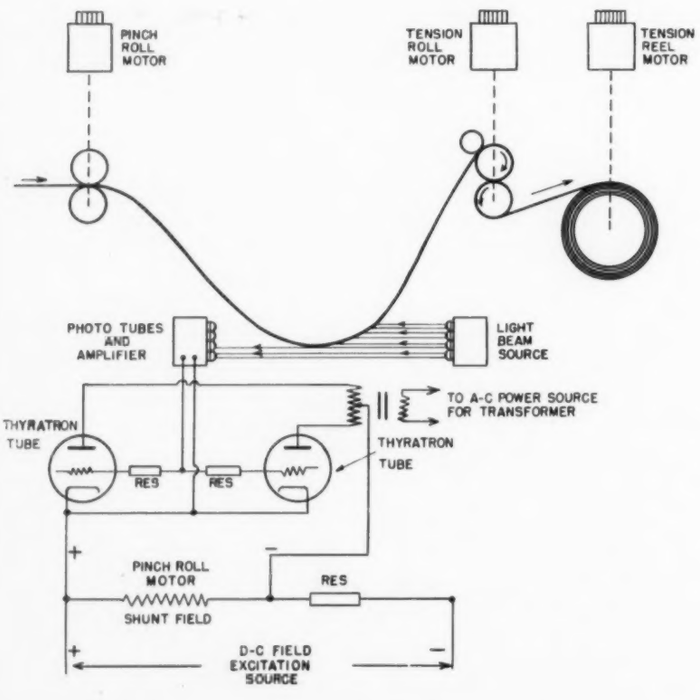
The reference field corresponds to the helical spring on, say, the vibrating contact of a regulator. Its direction is, in the case of the left reel, such as to strengthen the reel motor field. For the right hand, or winding reel, the reference field will tend to weaken the reel motor field. By opposing the current control field with the reference field, the regulating point of the amplidyne is the result of the net excitation of the current and reference fields.

The current control field gets its indication of reel motor armature current from across the resistor located in the armature circuit. Excitation of this field will be proportional to the armature current, for a given tension rheostat setting.

The forcing field alters the balance, between the reference and current fields, during the accelerating and decelerating periods. During acceleration of the mill, the field currents of the reel motors are altered so as to decrease the armature current of the unwinding reel motor (generator action) and to increase the armature current of the winding reel motor. The inverse "forcing" will take place during deceleration, the amount of forcing being determined by the inertia of all the rotating parts of the reels, as well as by the rate of acceleration and deceleration.

Thus, we have something old, yet new, with the amplidyne. The scheme is old in its principle of holding armature current. But the utilization of the amplidyne to replace vibrating regulators is comparatively new. Here is a regulator with speed and accuracy of response but which requires no more maintenance than that required by a conventional direct current generator.

Figure 19—Loop control on continuous cleaning line by means of photoelectric and thyratron tubes.



THYRATRON-PHOTOELECTRIC LOOP CONTROL

In some of the foregoing paragraphs the electrical control function was to coil or uncoil the steel strip at a constant tension, the magnitude of which could be changed by means of a tension adjusting rheostat. On many processing lines it is desired to uncoil or coil the strip, with no tension except that due to the weight of the strip itself. Examples of such processing lines are the steel strip continuous cleaning line, the trimming and shearing line, and the galvanizing line.

An elevation view of the finishing end of an electrolytic cleaning line is shown in Figure 19. The purpose of the pinch roll is to assist in pulling the strip through the processing tanks, while the tension rolls and the tension reel have the single function of rewinding the strip on the reel drum and at a practically uniform tension. The control of the tension roll and tension reel motors will not be discussed here, for their controls can be made similar to that on the strip grinder of Figure 14.

In Figure 19 the loop between the pinch rolls is controlled by varying the speed of the pinch roll motor. If there is a booster generator in series with the armature of the pinch roll motor, the pinch roll motor speed can be varied by changing the booster generator excitation. In the absence of a booster, the speed may be varied by changing the shunt field excitation of the pinch roll motor.

For simplicity, let us take the case of loop control by means of field excitation of the pinch roll motor. When the loop becomes too great, the field current will be increased so as to slow down the pinch roll motor. In the same way, the motor will be speeded up when the loop is not great enough.

A variety of means have been used for indicating the

amount of loop. During manual control of the loop, the operator observes the loop position and, accordingly, turns the field rheostat of the pinch roll motor to change the pinch roll speed. A mechanical limit switch can be located at the base of the looping pit. When the loop becomes too great, the weight of the strip will bear downward on the limit switch arm, while contacts in the limit switch control the motor field. Rider rolls have also been used at the lower part of the loop. The rider roll can be made a direct or indirect means of speed control.

In all the mechanical methods of loop control, the loop indicating device actually touches the strip. Such methods may not only be cumbersome and interfere with the operators, but the inherent mechanical inertia of such devices also impairs their operation as speed regulators. Inertia tends to promote sluggishness in response and to introduce "hunting".

Figure 19 shows a method of loop control which is now successfully in use. The control is completely void of any mechanical inertia and contains a minute amount of electrical inertia. Photoelectric, electron, and thyratron tubes, are the principal controlling devices. Nothing mechanical touches the loop, and the light beam source with the photo-tubes and their amplifiers may be almost completely hidden in "pockets" of the looping pit.

The horizontal light beam of Figure 19 is partially interrupted by the loop of steel strip, while the system is set to regulate the speed of the pinch roll motors so that the loop always remains in part of the light beam. The output from the photoelectric amplifier is a measure of the amount of light flux falling on the photoelectric tubes, and hence a measure of loop position. Thus, the two thyratron tubes receive their indication of loop position and regulate the motor shunt field strength by more or less "boost" voltage. Two such thyratrons are used in a grid controlled, full-wave rectifier circuit.

Briefly, we gain several things by using the photoelectric thyratron control of a loop. All mechanical limit switches and rider roll rheostats are eliminated; similarly, "dancer roll" mechanisms are not riding on the strip. Automatic loop control is accurately maintained during acceleration, normal running, and deceleration of the processing line. Finally, particularly where more than one loop is maintained at various points in the processing line, the operators may devote their attentions to other things, or one operator may no longer be needed.

CONCLUSION

There have been briefly described several instruments, some of which are new in application, and some novel control schemes which are being used in steel mills. In other words, such devices as the Wheatstone bridge, the variable air gap transformer, the amplidyne, the vacuum tube amplifier, and the thyratron, were described. Clearly, these new applications or inventions were not the result of either accident or necessity alone. They were more the result of the utilization of known devices to suit the constant yet changing needs of the steel industry. Much credit is due the steel mill industry and the mill machinery builders who have had the courage to give such new applications their first actual trial.

The author, Mark Twain, once wrote, "For Columbus to have discovered America was wonderful indeed; yet for him to have failed to find that continent would have been more wonderful". Perhaps new and improved devices eventually find their places in industry in just as certain a manner.

A. I. S. E. District Section Activities . . . . .

BIRMINGHAM, March 30—*"Blast Furnace Gas Cleaning"*, by A. J. Whitcomb, Freyn Engineering Company, Chicago, Illinois

CHICAGO, March 10—*"New High Voltage Air Circuit Breakers"*

CLEVELAND, March 16
YOUNGSTOWN ,March 17 } —*"Reclamation of Palm Oil and Transformer Oil"*, by R. P. Dunmire, Buckeye Laboratories Company, Cleveland, Ohio

DETROIT, March 10—*"Large Electric Furnaces Under Heavy Loads"*, by W. B. Wallis, President, Pittsburgh Lectromelt Furnace Company, Pittsburgh, Pennsylvania

PHILADELPHIA, March 5—*"Performance of Gases in the Oxygen Cutting Process"*, by P. L. Betz, Consolidated Gas, Electric Light and Power Company, Baltimore, Maryland *"Control of Galvanizing Kettles"*. by Howard Halstead, Assistant Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland

PITTSBURGH, March 9—*"New Developments in Lubricants for Rolling Mills"*, by Maurice Reswick, Standard Oil Company of New Jersey, Pittsburgh, Pennsylvania.

ATLANTA, GEORGIA

A. I. S. E. Meeting and Inspection Trip

BIRMINGHAM DISTRICT SECTION—Saturday, April 11, 1942, 1 P.M.—Inspection trip to the plant of Atlantic Steel Company, Atlanta, Georgia, followed by a technical meeting and dinner.

Electrolytic T

By

UNIT

Pittsb

▲ THE importance of the matter of electro-tin plating of steel strip stems from the magnitude of the tin plate industry. Probably from 1,500,000 to 2,500,000 tons of tin plate is produced annually, and about 80,000,000 lb of tin is required for the final product—tin cans. Despite tin being an imported product, and coating in excess of 50c per lb, its value as a protective coating in food canning remains pre-eminent.

Whereas, tin is predominantly coated on steel by the hot dip method, involving coatings of about 1.0 to 1.5 lb per base box (about .00009 in. max) there is a large portion of the field of application, where thinner coatings, were they commercially available, would be entirely acceptable. This is typified by such articles as coffee containers, tobacco tins, etc. classified as dry packs—and this general field is variously estimated to be from 20 to 40 per cent of the total production.

In the beginning of flat steel rolling and processing, the handling of the product throughout its manufacture was in sheet form for many then important reasons. As the art has progressed, the multitudinous advantages of processing in strip form have been demonstrated at practically all stages of production, except, perhaps strange to relate, in the coating. In hot dip galvanizing as well as hot dip tinning, the predominant equipment handles the product to be coated in sheet form, altho current developments in hot dip zinc coating forecast the successful advent of strip coating. In the case of tin, however, for tin cans, the product specifications are much more stringent, and have till now defied any attempts to hot dip coat in strip form successfully. These difficulties have been principally: inability in overcoming streaking of the coating due to flux adherence, etc., and inability in producing uniform coatings as thin as are possible in sheet form. There are, however, several continuous hot dip tin lines in production where heavier coatings are desired, and where the ultimate in coating uniformity is not of paramount importance.

Added to the above picture is the contemporary strategic importance of tin, and as has been the case for some years in Europe, an effort to economize in tin is undoubtedly indicated. Here again one of the primary attributes of electro-tinning can be called upon, and even if the electro-plating costs per se were higher, which they are not under proper circumstances, the saving in tin proper would more than justify the process.

Supplementing the possibility of plating to produce thin coatings, consistent with economy, are other attributes of significance. Uniformity of coating is worthy of mention. Whereas, coating thickness variations of 30 to 50 per cent are not uncommon in spot tests on hot dip tin plate, not counting the list edges where 100 per cent thickness increases may well be expected, electro-tin coating variations need not exceed 10 per cent even on wide strip, and consistent variations of less than 4 per cent are within reason. Of course, there are those protagonists who will maintain that electro-coatings are uniform to fractions of a per cent, but this cannot be substantiated in commercial practice. The natural tendency, in plating strip, with anodes at full strip width and equi-distant from the strip is to produce heavier coating thicknesses along the edges, due to the greater current density there. By suitably maintaining anode widths less than the strip width, and by further resorting to increasing the anode spacing near the edge as well as by the use of "current guards", very desirable coating uniformity can be obtained.

In coating thickness control, the electro-plating method again takes precedence over hot dip. Not that coating accuracies are not obtainable in hot dip methods, but the mathematical relationships between line speed, current density, etc. make the problem of thickness control in electro-plating an easy one, capable of quite large variations. This is not the case in hot dip practice, where empirical control thru exit roll pressure and contour are involved, all affected by speed, temperature, etc. Of even greater importance, is the possibility, peculiar to electro-plating alone of producing not only different coating thicknesses on either side of the strip, but no coating at all on one of the sides, or even different coatings on each side.

The impetus of production plating far in excess of present practices has resulted in great strides in tin plating at higher current densities. Whereas, only a few years ago, plating densities of 10 to 30 amperes per sq ft of cathode (strip) were limits, it is now commercially practicable to plate at from 300 to 500 amperes per sq ft, with double these figures not out of reason. The value of these advances is not of an unmixed nature, for altho plating tank lengths became greatly shortened, even at increased line speeds—and result in initial plant cost reductions—they also result in increased plating current costs, which may at times be a consideration. This relation is approximately evaluated by: Plating power cost = K.EIt, where weight of coating = cIt, so that for a given weight of coating, power cost is proportional to E; i.e., if the current density is increased by doubling the plating voltage (which may mean a doubling or trebling of current density) then the plating power costs will be doubled. Co-existent with these higher current densities are the problems of quality of coating surface, porosity, physical properties of plate, such as ductility, and even brightness of deposit. Perhaps contrary to general experience, electrolytes with proper addition agents have been developed which actually improve in ductility, maintain stability, and do not sacrifice in surface quality even at the high densities mentioned earlier.

Perhaps deserving of especial comment is the relative value of acid vs. alkaline tin electrolytes. Typical of the first is tin sulphate, and of the second, sodium stannate. Without going into electro-chemical detail, it is our belief that the acid electrolyte is much to be preferred. This is contrary to the feeling held at the inception of this general problem, and it was the conviction, principally held in England, that the stannate bath was better suited for steel mill conditions. This was principally based on the consideration that less

TINPLATE

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Presented before A. I. S. E.

ANNUAL CONVENTION, CLEVELAND, OHIO

exacting preparation of the strip for plating is required in the case of the alkaline electrolyte, which inherently has cleaning characteristics. But the limitations as to current densities, the disadvantage of its inherently higher specific resistivity, resulting in greatly increased plating current costs, legislate against its continued preference, and our plants of the future are predicated upon tin sulphate, with the all important addition agents.

An unsolved problem in electro-tinning is the present inability to produce satisfactory bright deposits. Brightness here, as in most other applications, is only a matter of appearance. Furthermore, it is felt that the present matte gray appearance of tin electro-deposite could not be easily argued into acceptance by the consumer trade. Efforts, therfore, have been made to bridge the gap between this finish and the relatively bright surface characteristic of fused tin. Altho there has been some measure of progress in obtaining brighter electro-deposits, but the attendant coating brittleness has been a more serious deterrent. This has resulted in efforts to brighten by special surface treatments immediately following plating. These have been principally along two lines: mechanical brushing and buffing; and by thermal reflowing of the deposited tin. Both of these possibilities yield acceptable product, and their relative advantages and disadvantages will be compared later, but suffice it to say that a commercial solution is at hand. There exists still a third possibility —that of electrolytic brightening, such as is gaining favor for stainless steel polishing, and also for general metallographic work. However, the times involved practically eliminate it as a commercial process at present writing.

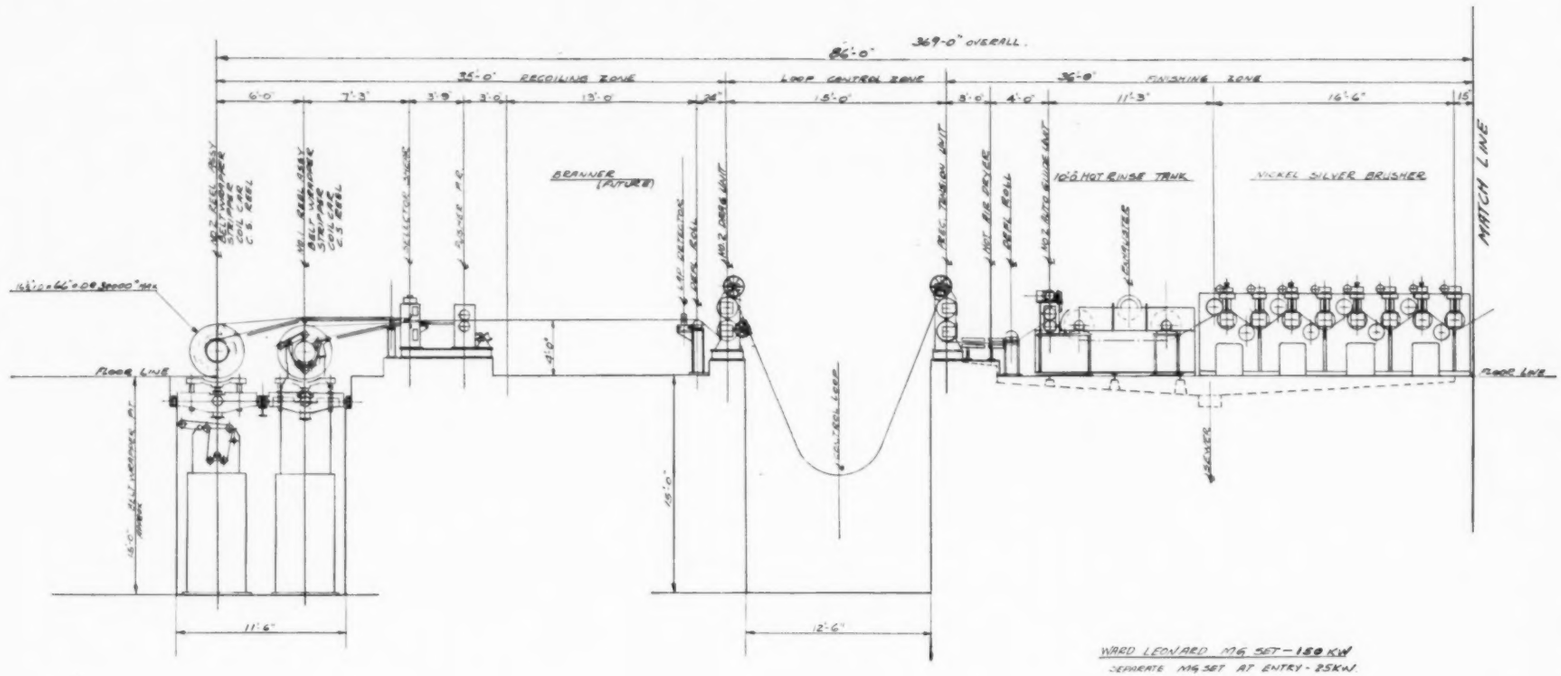
As to the matters of the bond between the electro-deposit and the base metal, soldering of the electro-tinplate, forming of the electrolytic product, lithographing of the plate, and the absence of any "aging" such as occurs in hot dip tinning, there is some more work to be done, altho a great deal has been accomplished and established. Naturally, the nature of the bond can be said to be mechanical in nature, whereas a hot dip tin bond is to some extent a diffusion bond. in that Fe-Sn alloys are formed, principally Fe-Sn_2. Despite this better bond from a strict adherence point of view, these alloys are fairly brittle in nature, and their disadvantage in forming is more serious in most cases than the somewhat better adherence—this is particularly so in the lighter coatings. The anticipated difficulties with soldering, due principally to the lighter tin deposits possible in plating have not been realized, for much can be and has been done in the "after treatments." As to porosity, improved results have been obtained for equal weights of coatings, due principally to the absence of low coating areas, no doubt. A virtue, yet to be fully realized, has to do with the "aging" that hot dip tin plate undergoes while being coated in the tin pots. This short time high temperature treatment results in a loss in ductility, altho is somewhat compensated for by increased hardness—and each combination of properties may have its particular virtue.

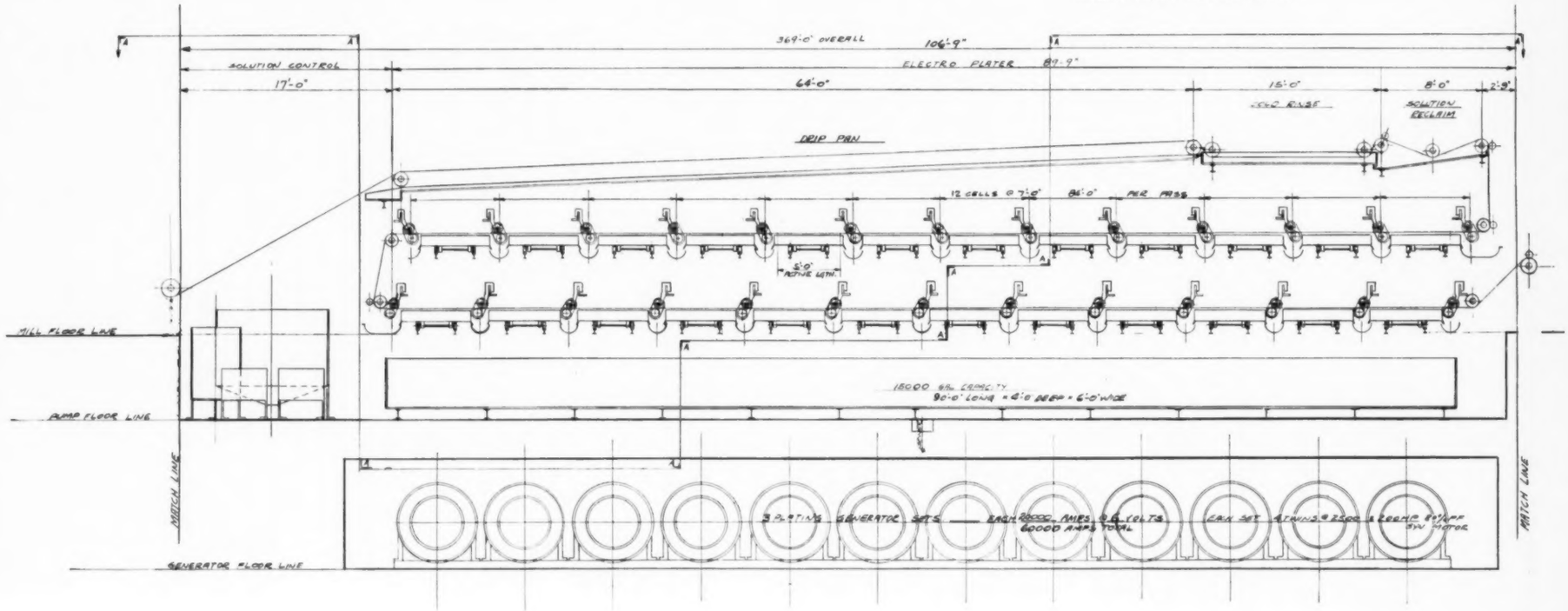
With the general situation somewhat critically surveyed, the immediate specific production problem can be formulated about as follows: What is required to electro-tinplate cold rolled, annealed, and temper passed low carbon steel strip with a coating weight of ½ lb per base box (.00003 in.) at 500 fpm—the strip being .007-.011 in. thick, 16-38 in. wide, in coil lengths from 5000-10,000 ft and coil weights of 6000-12,000 lb? This task was assumed by the writer's company together with another company some three years ago, and a pilot plant was built to evaluate the various factors. Let it be said at this point that the problem was solved in a commercially satisfactory manner, and now the experience is behind us that will permit expansion of the industry in this direction.

The problem naturally divides itself into two major categories—the chemical or electro-chemical, and the mechanical. Although the first category is necessarily the basic one, and must form the foundation of any plant, the second aspect must be given equally as much attention—for many processes have fallen short of their potentialities due to improper mechanization.

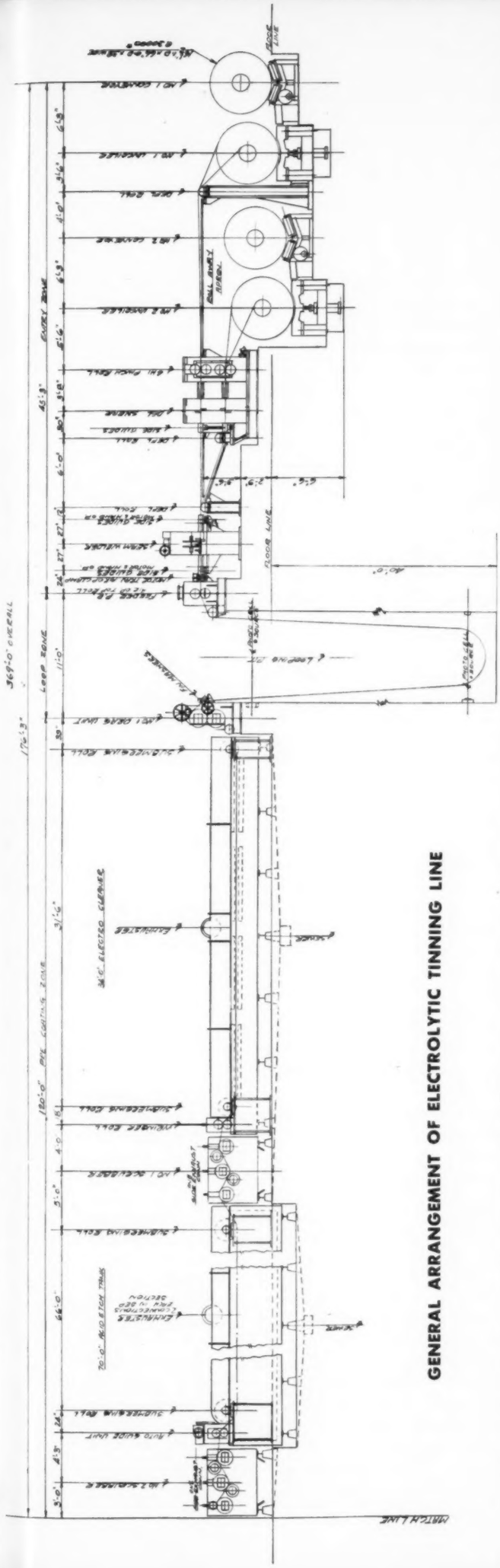
Strip to be electro-tinned is usually prepared in the following manner: hot rolled and coiled; continuously pickled and recoiled; cold rolled some 80 per cent; continuously electrolytically cleaned to remove rolling oil prior to annealing; coil annealed; and temper passed. In this latter condition, the strip is quite bright, essentially free of scale or oil, and retains a certain measure of stiffness. Following the dictates of the best plating practice, it has been deemed advisable to pass the strip thru both an electrolytic cleaning treatment and a pickling treatment prior to plating—and incorporated in the same processing line. The defense for the first operation is not that there is any definite oil to be removed, since temper passing is done dry, but rather the insurance that any accidental dirt or oil that may be dropped on the strip be certainly removed before it results in an improperly plated spot, which may condemn an entire coil, or at best require subsequent inspection at an inconvenient point in the manufacture. About a 3-sec dip in an electrolyzed cleaning solution, followed by a combination scrub and rinse seems to entirely answer the requirments.

The matter of pickling is perhaps somewhat more imperative, and our ability to accept so little pickling,


86'-0"
369'-0" OVERALL
35'-0" RECOILING ZONE
LOOP CONTROL ZONE
36'-0" FINISHING ZONE
6'-0
7'-3"
3'-9
3'-0
13'-0
26"
15'-0"
5'-0
4'-0
11'-3"
16'-6"
15
MATCH LINE
BRANNER (AFTER)
#2 REEL ASSY
#1 REEL ASSY
SELECTOR SHOE
SCRUBBER #2
#1 DETECTOR
#2 DRIVE UNIT
REEL TENSION UNIT
HOT AIR DRYER
DEFL ROLL
#2 ACTIVATING RINSE UNIT
100 HOT RINSE TANK
POLISHERS
NICKEL SILVER BRUSHER
CONTROL LEVER
BRUSHER
FLOOR LINE
FLOOR LINE
11'-6"
12'-6"
WARD LEONARD MG SET - 150 KW
SEPARATE MG SET AT ENTRY - 25KW.


369'-0" OVERALL
106'-9"
ELECTRO PLATER
89'-9"
SOLUTION CONTROL
17'-0"
66'-0"
15'-0"
8'-0"
2'-9"
SOLUTION RECLAIM
DRIP PAN
12 CELLS @ 7'-0"
86'-0" PER PASS
5'-0" ACTIVE WTH.
MILL FLOOR LINE
PUMP FLOOR LINE
18000 GAL CAPACITY
90'-0" LONG x 8'-0 DEEP x 6'-0" WIDE
MATCH LINE
GENERATOR FLOOR LINE
MATCH LINE

369'-0" OVERALL
176'-3"
180'-0" PVC COATING ZONE
LOOP ZONE
45'-3"
ENTRY ZONE



GENERAL ARRANGEMENT OF ELECTROLYTIC TINNING LINE

relatively, is continuously the wonder of the hot dip practitioners. Here, however, the matter of actual scale removal is not at issue, but rather the etching of the surface to provide a better bond. A 5 to 10 sec flash in a more or less conventional sulphuric acid bath seems adequate, altho electrolytic pickling may be substituted satisfactorily, particularly if space is a limitation, and the reduction in pickling time is taken advantage of. This again should be followed by a lukewarm scrub and rinse prior to entry into the plating operation. Both of these preliminary treatments offer no especial mechanical difficulties, particularly as to cleaning, where commercial cleaning speeds are at present in excess of 2000 fpm. Steel pickling equipment is not usually run at speeds as high as 500 fpm, and in this case, it means only that the pickling tanks be long, if we wish to avoid vertical looping in shortened pickling equipment, to avoid having to contend with bearings running submerged in acid.

The plating unit proper, of course, has naturally received the greatest amount of attention and study. Certain principles have been recognized and developed which dictated the design of the unit, and adopted: Plating is preferably done on the underside so that no impurities from the anodes may fall on the work, and produce porous spots, and a rough top coating, altho plating vertically will tend to get away from this objection, particularly if the strip passes through on edge; the highest current densities compatible with power economy require values, as mentioned earlier, of 300 to 500 amperes per sq ft and more, so that plating tank lengths may not be greater than 30 ft to 40 ft; it is desirable to permit different thicknesses of tin to be plated on either side, perhaps none at all on one of the sides, or even another type of metallic cost; electrolyte should be circulated at high speeds in the vicinity of the work as well as the vicinity of the anodes, to permit higher plating densities in the former case, and reduce polarization in the latter; anodes should be as close to the strip as possible to reduce power requirements, and be adjustable as well, to prevent voltage increases as the anodes are used up; anodes might advisably be rotatable, not only to permit uniform usage of same, but to further reduce polarization—and must be designed to be replaceable during continuous operation of the line; current collection contacts must be so designed that too high current densities in the strip proper do not exist, lest a momentary stop result in the strips melting apart, altho automatic reduction of plating current with speed or automatic current shutoff when strip tension is lost would ameliorate this situation effectively. These primary considerations and many other allied factors have resulted in a plating tank design in which the strip is first plated on the underside, after which the strip reverses on itself on an upper level where the other side is plated as desired, after which the strip direction is again reversed thru a rinse tank and dragout reclamation system. The operation of such a unit as described above at commercially desirable speeds is now a demonstrable fact.

As to the matter of brightening the matte electrodeposit, the mechanics of operation are much simpler and more controllable in the case of brush brightening. By using fine nickel silver wire brushes, properly

bonded, and micrometrically trimmed and adjusted, operating at high speeds, a bright finish resembling a satin stainless steel surface is readily obtained. This type of surface is considered by some even more attractive than hot dip, particularly because of its uniformity, and with proper operation, the porosity of the brushed plate may be even better than the plate as deposited—due apparently to a slight burnishing action. Large variations in line speed do not appreciably affect the finish.

The alternate method of brightening tin plate, by reflowing the electro-deposited tin, produces a surface closely akin to hot dip plate, even to the fern-like surface crystals, so often discernible. However, heating the tin to a temperature above its melting point must be carried out in conjunction with fluxing or wetting agents which accelerate the surface brightening phenomenon to the point that "running" or "streaking" is forestalled. Then, too, with variable line speeds, particularly during strip joining, great precautions must be taken to properly alter the melting rate to maintain good surface conditions. These difficulties are to be balanced against the remanent prejudice for the hot dip type of surface that still exists to some extent, and the possibly better porosity characteristics of the plate.

The drying and oiling operations which follow the brightening will vary according to the brightening method adopted. After scratch brushing, for instance, the electro-tinned strip is passed thru a hot rinse, and subsequently dried in a blast of heated high velocity air. In this case, the tinned surface must be oiled very slightly to prevent oxidation of the tin and scratching; and yet permit the cut length sheets to depile rapidly in the can making machine, without sticking. Oiling roll machines and sprays have proved inadequate for this purpose, and a special synchronized branning machine has been developed for this purpose, which has controlled oil content and temperature, and in which the bran is pneumatically fed into the bites of super- and sub-strip speed rolls arranged above and below the strip to properly apply the oily bran. The machine acts, as well, as a sort of buffing machine, in which the lustre is somewhat heightened.

The mechanical aspects of such a line as we are concerned with are our next concern. The handling of the strip is broken up into three zones: the uncoiling zone, the processing zone, and the recoiling or shearing zone, as the case may be. In the uncoiling zone, double uncoilers must be fed from dual coil feed lines for continuity. These uncoilers are of the cone or expanding type, so that the surface of the strip is not touched, and are hydraulically adjustable laterally for variable coil widths and centering, and are provided with hydraulic lifts for rapid coil placing between cones.

The succeeding operation, that of rapid and accurate joining, involves two machine elements: a combination 4-high pinch roll stand and integral shear, and a combination double seam welder and integral shear. The 4-high pinch roll stand is arranged with the two intermediate rolls vertically operable together, so that only one or the other of the pinch roll units are in contact at one time. While the strip being processed is passing thru the open rolls, the other unit is used to advance the front end of the strip of the coil being prepared, thru the integral shear, where its front end is sheared square and true in readiness for joining. As the rear end of the strip being processed approaches the welder, the operator brings zone I equipment to a halt, permitting continuity of operation in the other two zones by the interposition of a looping device. The strip is then clamped in the welder, and the rear end sheared accurately and within $\frac{1}{16}$ in. of the rear welding wheel face. The front end of the oncoming strip is then advanced to a stop fixed $\frac{1}{16}$ in. ahead of the forward welding wheel, and the two strips clamped, while the double seam welder is run across the accurately fashioned lap at speeds approaching 50 fpm. The resultant lap weld joint is strong, neat, and has no projecting ends that will in any way foul subsequent processing apparatus, such as, say, the scratch brush units, which must be at all times in accurate adjustment and good condition. The total overall "down time" to perform this joining operation takes from 15 to 30 seconds, depending on the strip width, gauge, etc.

The final unit in zone I is a rubber covered pinch roll unit that serves to uncoil the strip off the active uncoiler, and to maintain the proper amount of strip in the succeeding looper, for continuity of operation. Zone I equipment, as well as all other equipment is operated off an external Ward-Leonard speed control set, by which the entire line may be operated from 0 to 500 fpm, with all units properly synchronized during the acceleration and deceleration periods, as well as during continuous operation.

In order to permit full maximum speed line operation of 500 fpm even during the joining time, a looper capable of controlling in excess of 250 ft of strip would be involved. Whereas, this is a possibility, a machine of this sort would entail many moving looping rolls so arranged that no scratching is permitted. The further problem of maintaining all such rolls truly parallel during motion, especially after wear, in order to maintain proper guiding of the strip has resulted in our interim adoption of a looping pit, involving considerably less strip. By providing, for instance, a 40 ft deep looping pit, in which 80 ft of strip could hang freely without danger of scratching, it would be necessary to slow the line down only to 160 fpm during the joining operation. For 10,000 ft coils, the slow down would only mean about a 2 per cent reduction in production, and for the time being, this is being neglected. The matter of coating control may easily be taken care of in this case by automatically interconnecting Ward-Leonard set control to the plating generator field control to maintain a constant relation of strip speed and current density.

Zone II equipment covering essentially all processing equipment is operated so that it preferably never stops. This involves all the equipment discussed earlier, with the addition of a drag tension machine, a master pull tension unit, and one or more automatic guiding units. The pull and drag units mentioned are really inverted machines, in which the strip wraps around at least two rubber covered rolls either mechanically or electrically connected together to act as "flying winches". These units, one at the delivery end of the zone, and the other at the entry end, serve to positively keep the strip moving at a controlled speed and tension, and this latter is of great importance.

Zone II ends at the master tension pull unit, after which a slight operation loop is maintained for purposes of strip guiding so that accurate, straight sided coils may be produced. Following this loop, zone III begins with a drag tension unit, against which the coils are reeled. This is followed by the branner, placed at this somewhat delayed point to prevent oil from the branner getting on the tension unit rolls and interfering with their proper operation.

The continuous recoiling equipment consists of a combination up-and-down pneumatic snip shear and deflectors, two collapsible reels and individual belt wrappers, dual reel strippers and coil receivers, all automatically operable from a magnetic pickup that recognizes the approach of the end of the coil. The sequence of automatic operations is started off when the lap weld passes thru the gap of the magnetic pickup, which without touching the plated strip, with its attendant danger of marking, set off three operations: thru a variable time delay relay, operates a solenoid operated air valve that causes the pneumatic snip shear to part the strip (at high speed) just behind the lap weld, which mechanism at the same time operates the strip deflector to directionalize the strip into the receiving reel; brings a pair of pinch rolls, normally open, which are located ahead of snip shear, into engagement with the strip, to advance the newly created front end into the reel; and starts the empty receiving reel to rotate, at the same time, bringing its belt wrapper into entering position. Once the strip makes a few wraps around the reel, the belt wrapper is retracted into a sub-basement below the reel, and the operator turns his attention to removing the newly formed coil from the first reel. This is done by collapsing the reel, which may be done manually, and a combination elevator and stripper unit slides the coil off the reel drum onto a solid receiving mandrel, which is brought up against the end of the reel by an hydraulic cylinder or onto a tilting coil receiver, whichever is preferred. The mandrel is then retracted, and all is in readiness to receive the next coil. This part of the operation can be performed leisurely, and the coil removed from the mandrel by ram truck or crane, at any convenient moment—since the time interval between coils may range from 10 to 20 minutes, even at maximum operating speeds. Any necessity for reeling electro-tinned strip between paper wrapping was almost immediately dispelled, as good reeling results in no scratches.

The matter of delivering electro-tinned coils to the tin can industry is something that is probably anticipatory, although some is being done this way at the present time, and this tendency will most certainly develop, as it has in the autobody sheet field. To deliver electro-tinned sheets requires a synchronized flying shear capable of shearing various lengths from 14 in. to 36 in., at various speeds up to 500 fpm, with tolerances plus or minus $\frac{1}{64}$ in., so that resquaring is not necessary. The ability to do just this actually set the maximum speed of the pilot line at 500 fpm, altho speeds in excess of this are now realizable. In conjunction with this shear is an electric pin hole detector as well as a flying micrometer, so arranged that either defective material or off-gauge strip—either light or heavy—will be automatically discarded. This is done by means of a sorting type piler, which comprises two or three upwardly inclined conveyor belts which receive the cut lengths as they leave the shear—leading to two or three piles, as the case may be. The strip is directionalized to one or the other of these conveyors by means of solenoid operated deflectors, operated by the discriminatory drive in question. In a production set up, it may be desirable to shear in a separate line, to avoid production line interruption that the care and adjustments of shears entails. Then, too, a side trimming operation is justifiably performed ahead of the plating to avoid bad rolled edges from unnecessarily cutting the rubber covered handling rolls. This equipment might well be included as a part of zone I equipment, altho there may be some that would prefer it to be a separate preceding operation.

In long processing lines of this type, when thin wide strip is to be handled at high speeds and under tension, the matter of guiding is a problem of paramount importance. For this reason alone, low or zero tension loops are necessarily introduced in the line at preferred locations at even some equipment expense to permit the use of roller or "fin-masher" type guides. This practice follows along the experience that anyone has had in attempting to guide a belt along a pulley face on the loose side as compared with the tight side. Side guiding of tensioned thin strip is undesirable or even impossible in that the edges will turn up before any appreciable guiding force can be exerted, and a spoiled product is the result. In our pilot line, such guiding is effected at two locations, namely—at the two loops immediately preceding and succeeding the processing zone. However, this processing zone remains so long, in itself, and is preferably operated in a continuous tension zone, that a new type of automatic guide was developed and built to control guiding even under tension. This device works on the principle of automatically creating tension on the edge of the strip away from that toward which it is wandering, as recognized by suitably placed photocells, which causes the strip to tend to center itself—all without guides in contact with the edges proper.

The pilot installation referred to earlier had as its goal the evaluation of the various and multifarious factors described in this paper. They have been sustained or modified, as the case might be—and the result seems to us to be a true commercial answer to the question posed at the outset. Not only have we demonstrated that lighter coat tin plate can be produced, resulting in a saving of two-thirds of the tin, involving an appreciable cost reduction in itself—but further that the conversion costs in electro-tinning can be actually lower than for hot dip. This occurs, however, at line speeds in excess of 300/400 fpm, since the labor costs, installation charges, etc. remain constant, and, of course, is influenced by the local prevailing power rates. A 5-man crew and supervisor should operate a line such as described here, and should turn out 5,000 to 10,000 tons per month, depending on the gauges, widths, and diversity of orders. The operation of this line has brought to a focus types of operating problems for which there has been little or no precedent. The mechanics of providing a continuous supply of anodes, provision for their adjustment and replenishment, during uninterrupted operation, arrangements for accommo-

dating varying strip widths, etc. have all had their proper attention. The matters of solution handling, such as pre-mixing, filtering, reclaiming have had their innings. Even the questions of proper personnel had to be given consideration, since equipment of this type demands somewhat different and possibly better trained operators than steel mills have required in the past for similar operations.

The development covered in the text of this paper not only involved companies specializing in plating technique and equipment, as well as strip handling and processing equipment, but also depended, to a large extent, on the steel producing company that collaborated in the operation of the equipment. As is usually true of all major developments, the end was achieved as a result of united effort.

DISCUSSION

PRESENTED BY

CARL G. JONES, *Special Engineer,* Campbell Works, Youngstown Sheet and Tube Company, Youngstown, Ohio

M. D. STONE, *Manager,* New Development Engineering, United Engineering and Foundry Company, Pittsburgh, Pennsylvania

C. LYNN, *Manager,* D-C. Generator Engineering, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania

H. P. MUNGER, *Superintendent of Electroplating,* Republic Steel Corporation, Monroe, Michigan

C. J. DUBY, *Chief Engineer,* Republic Steel Corporation, Warren, Ohio

R. J. WEAN, *President,* Wean Engineering Company, Inc., Warren, Ohio

A. L. MILTON, *Engineer,* Wheeling Steel Corporation, Steubenville, Ohio

A. H. BRISSE, *Development Metallurgist,* Carnegie-Illinois Steel Corporation, Gary, Indiana

A. L. NIELSEN, *Development Engineer,* Sharon Steel Corporation, Sharon, Pennsylvania

J. C. McCURLEY, *Electrical Engineer,* Republic Steel Corporation, Warren, Ohio

CARL G. JONES: When you run up the current density, you run up the power cost, but do you run up the power cost per unit, as per foot or ton?

M. D. STONE: Per ton, yes. In other words, say, a ton of tinplate requires, if you are using a pound per base box, 20 pounds of tin. Twenty pounds of tin requires a certain number of ampere-minutes to put it on, whether it is plated at high or low current densities; say you put it on at 100 amperes per square foot. That requires a certain voltage. If you plate at 200 amperes per square foot, the plating time will be approximately half. Assume for the moment it is half. As you are going to plate at double amperage, the ampere-minutes are constant. Therefore, your volts times your amps times the time which is the power, is proportional to the voltage itself, and if it is double the power cost is double.

CARL JONES: But you ran twice as much, didn't you?

M. D. STONE: No—the line speed was held constant, but the plating tank length is assumed half as long.

CARL JONES: Consider your power per square foot of 1/30,000 in. coating. Now if you run 200 amperes per square foot, and you run twice as fast, you still get 1/30,000 in. of coating.

M. D. STONE: If you are going to plate at double density, of course, there are various things you can do. If you plate at twice the density, you can obtain the same tonnage by cutting the plating tank length in half. Let's do it that way. That is, total ampere-minutes for the number of square feet that you are going to produce, (say, a ton of steel means a certain number of square feet) is constant, no matter what the speed or current density. In one case you do it with certain voltage, and in the other you do it with double that voltage.

CARL JONES: You mean to say that if I plated at 400 amperes per square foot, whatever my speed might be, and get 1/30,000 in. coating it is going to cost more money than if I run 100 amperes square foot?

M. D. STONE: Yes, it will cost approximately four times as much in plating cost or plating power for a given surface covered or a given tonnage.

C. LYNN: I think I can make Mr. Jones' question a little clearer. When he doubled the amperes, he doubled the speed of his product, but he took twice the voltage, so that means four times the power with twice the production or double the power cost per unit production. Doesn't that come out correct?

M. D. STONE: That is good.

C. LYNN: I have a question I would like to ask. I understand that you said the possibilities would be from 300 to 500 amperes per square foot. I assume that is on one side.

M. D. STONE: Yes.

C. LYNN: And if you have a strip about three feet wide and plating baths about 40 feet long, making 60,000 amperes maximum on each side or 120,000 amperes for this plating unit, if it went to the maximum —have you gone that far, and if so, what voltage is required to put that heavy current through?

M. D. STONE: In this pilot plant I speak about, we haven't operated full widths.

The second question is a very difficult one. It varies very much with the electrolyte, the type and design of anodes, whether they rotate or not, with the circulation of your solution, etc. There are so many factors that any attempt to give an answer would be conjective, but if you are just interested in general values, it will vary between six and twelve to fifteen bolts.

H. P. MUNGER: Mr. Stone has given us a lot of detailed information about electrolytic tinplating. There is one subject that we cannot put too much emphasis on. As is well known to all electroplaters, cleanliness is one of the most important factors in getting good electroplating. Too much emphasis cannot be put on the fact that the strip must be clean to get good products.

There are two questions in reference to current efficiency and current density that I would like to ask. Do you have a balanced bath? Does the tin tend to build up in the bath, or is it depleted during operation?

M. D. STONE: Current efficiency, of course, varies with the type of electrolyte. It isn't necessarily the same at both the anode and the cathode. If they were equal at one condition, as polarization sets in, and sometimes it is bound to in this particularly high current density condition, that relationship might be upset. If so, you would be plating out of your solution at some time or plating into your solution, and you might have to check your concentration of tin in the solution and modify your efficiencies, which you can do by varying the spacing to maintain essentially constant tin sulphate, for instance, or constant percentage of tin in the bath.

As to the efficiency, as I say, that varies very much with the bath. But efficiencies that we have worked with have been considerably in excess of 90 per cent for both anode and cathode efficiency.

H. P. MUNGER: You have encountered no difficulty in keeping a balanced bath?

M. D. STONE: No difficulty is encountered in the operations as we have them.

H. P. MUNGER: The other question is regarding the cathode current density and the anode current density. You mentioned up to 300. What is the anode current density which you can use without polarizing your tin anode?

M. D. STONE: I can give you a general idea. It is desired to keep the anode current density as low as possible, so you make your area of anodes some larger than the area of the cathode. As far as specifically stating what the current density is at which polarization will or will not take place, that varies with the type of electrolyte. It will also vary with the agitation of your solution and whether you rotate your anodes or not, as I mentioned earlier. Those factors greatly influence the value. I might say between 150 and 250 amperes is probably an anode density, if properly designed, that you could run at without any serious polarization.

C. J. DUBY: This is a question on the looping pit. Would it be well to have a mechanical device to hold the looping pit in, due to the soft plate?

M. D. STONE: The way we operate the line, and I think the way it should preferably be operated, is for the loop to hang freely. There is no problem of cross breaks. We don't run into that and wouldn't expect to. At the harder tempers it won't show up. It might show up in annealed material with practically no temper in it, but if you hang it freely and easily, you won't have difficulty at all.

C. J. DUBY: Another question is on the design. The floor space permitting, wouldn't it be well to produce the electrolytic plate at reduced current density?

M. D. STONE: The simple answer is, yes. There are a lot of matters to be balanced one against the other. I would say that is correct. That would be the proper way to develop the line commercially, and that gives you additional length so you can step your densities up later and your tonnage, and so forth.

R. J. WEAN: Do you start out with a fluxing method after electrolytic tinning for the brighter finishes? I would like to know if you are prepared to say how much or if any alloy takes place between the tin and the base metal, forming tin iron alloy, by that fluxing process, and if so, approximately how much.

M. D. STONE: Our experience along that line has been very meager, so I couldn't say how much. It is a very controversial subject, as you know, as to whether it does at all. But I personally think it ought to be a little bit. After all, it has to be in the bath a matter of a fraction of the time the steel is in a hot dip bath and it alloys there, so I would expect to some extent it would alloy in the reflowing bath as well.

R. J. WEAN: Would you be prepared to say how wide the pilot plant finally was, that was the maximum width in inches that could be coated?

M. D. STONE: It was about twelve inches.

A. L. MILTON: I believe that in some of the early attempts of electrolytic tinning, a so-called "precoat" of copper or iron was used. Is that unnecessary how?

M. D. STONE: That depends on what use you want to make of the product. Precoating, of course, is expensive. It requires dual operation, dual plating. The combination of the two coats ought, if properly selected, to improve the porosity of the coating, but for the tin can industry, which is what this thing is primarily aimed at, to replace hot dipped tin, I would say it is not necessary.

A. L. MILTON: One other question. You spoke of the anode revolving, and as it deposits away, it must be brought closer to the strip. Does someone have to raise the anodes by hand or is that an automatic proposition?

M. D. STONE: I think we would not attempt to make it automatic at the outset. It is bad enough to have to do it. To make it automatic would be distinctly a chore. The advisability of even doing it is a question at the moment. You balance doing that against the additional cost of plating involved by having to raise the voltage as your anodes deposit away. So I would say it wouldn't be practical at the present time, and I would give it serious consideration as to whether you would do it at all, at the moment.

A. H. BRISSE: In connection with the mentioned polarization of tin anodes, have you actually observed its occurrence at higher current densities?

M. D. STONE: Yes, an increased voltage drop is noticeable when this polarization occurs.

A. L. NIELSEN: I would like to take up the question again, concerning the use of an undercoating between the steel strip and the electroplated tin coating.

As has been very well pointed out by Mr. Stone, electro-tin is of primary interest in reducing the amount of tin used. If the proper undercoating is applied prior to the electroplating of the tin, the porosity can be eliminated even with the thin tin coatings which have been discussed here today. Pores in tinned surfaces are caused by foreign particles such as oxides, specks of slag, etc., imbedded in the surface of the strip which are not "wetted" by the tin. The tin pulls away from these spots, leaving areas of the basic metal exposed. If, however, the strip is first electroplated with a high melting point metal, the imperfections in the base metal surface are covered up, leaving an outer surface which will receive the tin coating in a continuous and unbroken layer.

In the electro-tin process which uses an electroplated undercoating, cold reduced steel strip is taken directly from the cold reducing mill and passed continuously through the undercoating electroplating line; the conventional cleaning line for the removal of rolling mill oil is not needed. Usually about .009 ounces to .018 ounces of undercoating metal per square foot of strip surface is sufficient. The strip with the undercoating metal is then annealed and skin rolled in accordance with standard practice for cold reduced steel strip. Following this the strip is passed continuously through an electrotinplating line, where one-fourth pound to three-fourths pound of tin per base box is electroplated on the surface of the undercoating metal. In the same line the electroplated strip is heated to a temperature above the melting point of the tin, causing the tin to flow in a continuous and unbroken layer over the surface of the undercoating metal, and then the molten tin layer is quickly quenched, thus producing a pore free tinplate with a brilliant mirrorlike finish. This process is also commercially available at the line speeds mentioned by Mr. Stone.

If copper or bronze is used as an undercoating, an excellent pore free tinplate can be produced even though the tin is only about one half pound per base box, but at the present time most of the canning industries object to the use of copper as an undercoating metal when the tin plate is used for canning of food products because of possible contamination of the food from contact with the copper. There is some disagreement as to whether or not this contamination can take place because the finished tin plate consists of: (1) an outer layer of unbroken pure tin, (2) under the tin is a film of tin rich bronze, (3) a layer of pure copper and (4) copper-iron alloy next to the steel base.

However, if, in place of the copper, other metals are used, for example, pure iron or iron-nickel alloy, an excellent quality, pore free tinplate which is satisfactory for canning of all types of food products can be produced, and further more this superior tin-plate can be produced at a cost less than the cost of regular hot-dipped tinplate.

The point I wish to make clear is that if you do use an undercoating you may reduce the amount of tin used and at the same time produce a better quality tinplate at a reduced cost.

J. C. MCCURLEY: You said the acid pickle, just in the plain process, was a flash pickle to put an etching on the plate preparatory for plating. As it is not an electrolytic pickle, once you slow down for your end section of the strip, you get three to one ratio on your speed. Will the over-pickling during that time cause any particular difficulty in connection with the surface of the strip that might follow through the pickle bath?

M. D. STONE: No. The pickling could be electrolytic to shorten up the space required for this action, and you could then introduce control, if you wished; but we have done the other thing, and there is no deleterious effect by holding the steel in the bath that much longer. Actually, the effect is almost indiscernible anyway.

J. C. MCCURLEY: Another question in regard to the current density. Is it a fact that the quality of the plate that you get is a function of the current density? For instance, if you electrically operate a line at 300 amperes per square foot, and when you slow down decrease the amperes per square foot in proportion, would that change the quality of the plate?

M. D. STONE: Not essentially. But I would say that as a general thing the quality does change somewhat with density. In usual plating, it is generally agreed that as the plating density goes up your quality gets worse. It usually gets more brittle and rougher. But electrolytes have been developed, and the one we have worked with has exhibited a rather reverse tendency in that it did not get worse but possibly gets better.

There might be even some electrolytes developed that would show no effect, but we cannot say categorically that there isn't such an effect.

J. C. MCCURLEY: Would there be enough so that there would be a difference in characteristic between one portion of the strip and another portion?

M. D. STONE: Not that we have recognized in the product.

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Annual Spring Conference . . .

MONDAY, TUESDAY,

APRIL 27, 28, 1942

Royal Connaught Hotel

Hamilton, Ontario, Canada

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Program

MONDAY, APRIL 27

2:00 P.M.—Inspection trip, Dominion Foundries and Steel, Ltd.

6:30 P.M.—Dinner

8:00 P.M.—Technical session

TUESDAY, APRIL 28

9:00 A.M.—Technical session

2:00 P.M.—Inspection trip, Steel Company of Canada, Ltd.

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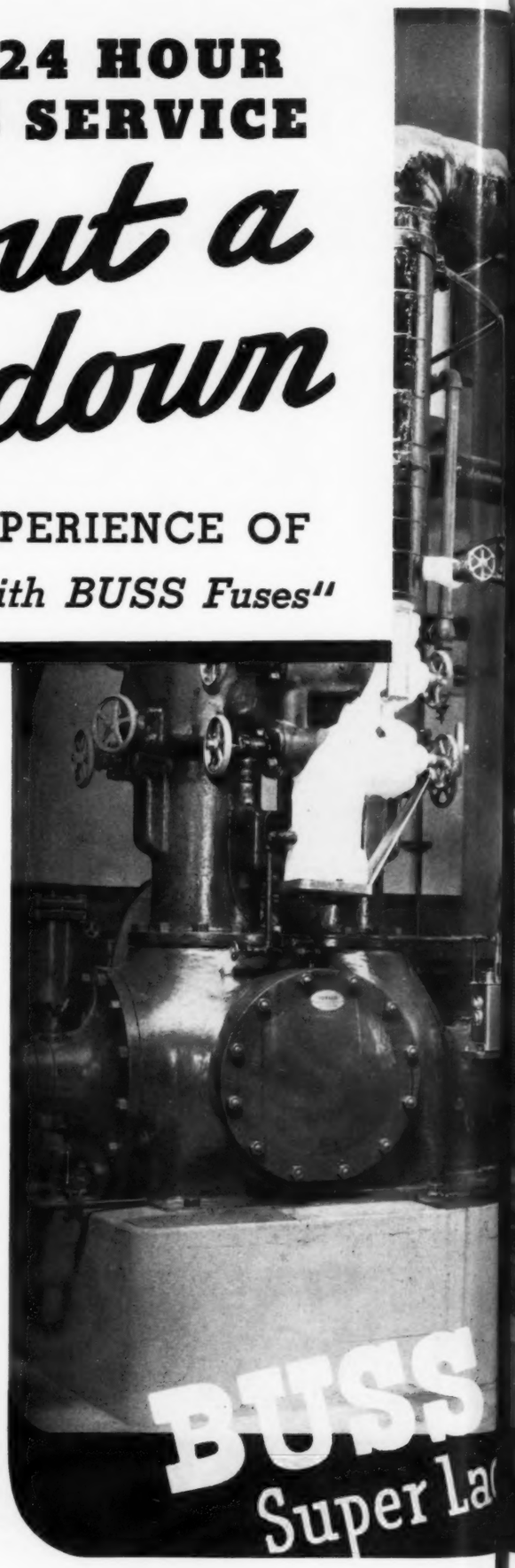

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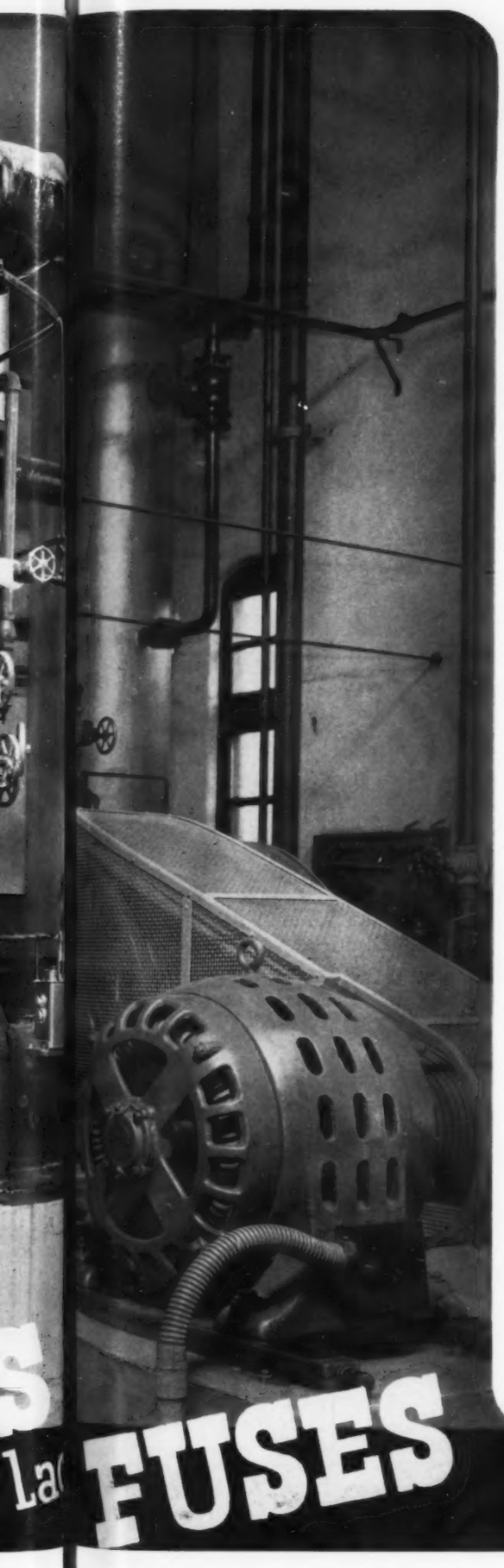
"We thought you would be interested in this information as it is typical of the experiences our customers are having with BUSS Super-Lag fuses."



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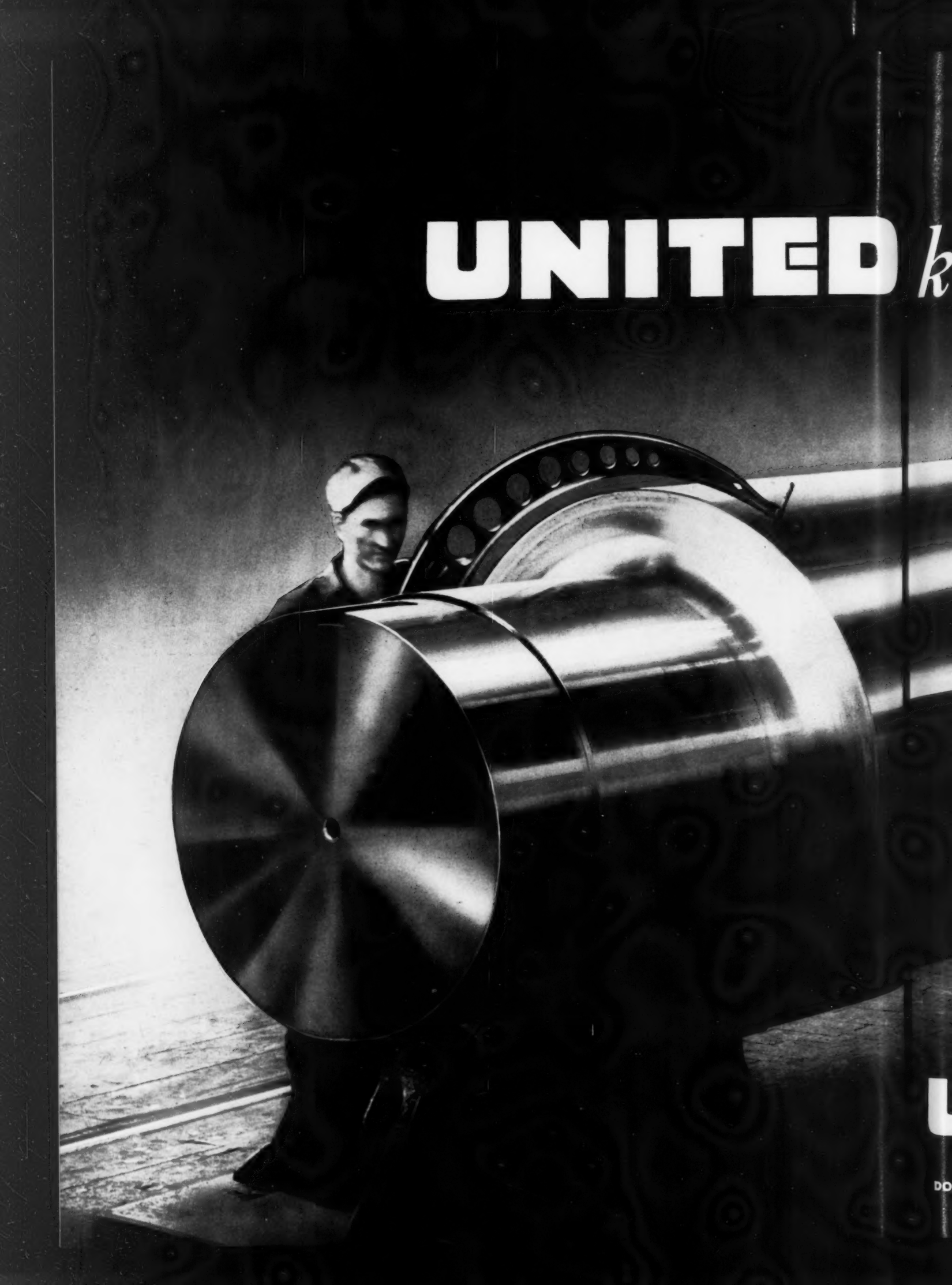
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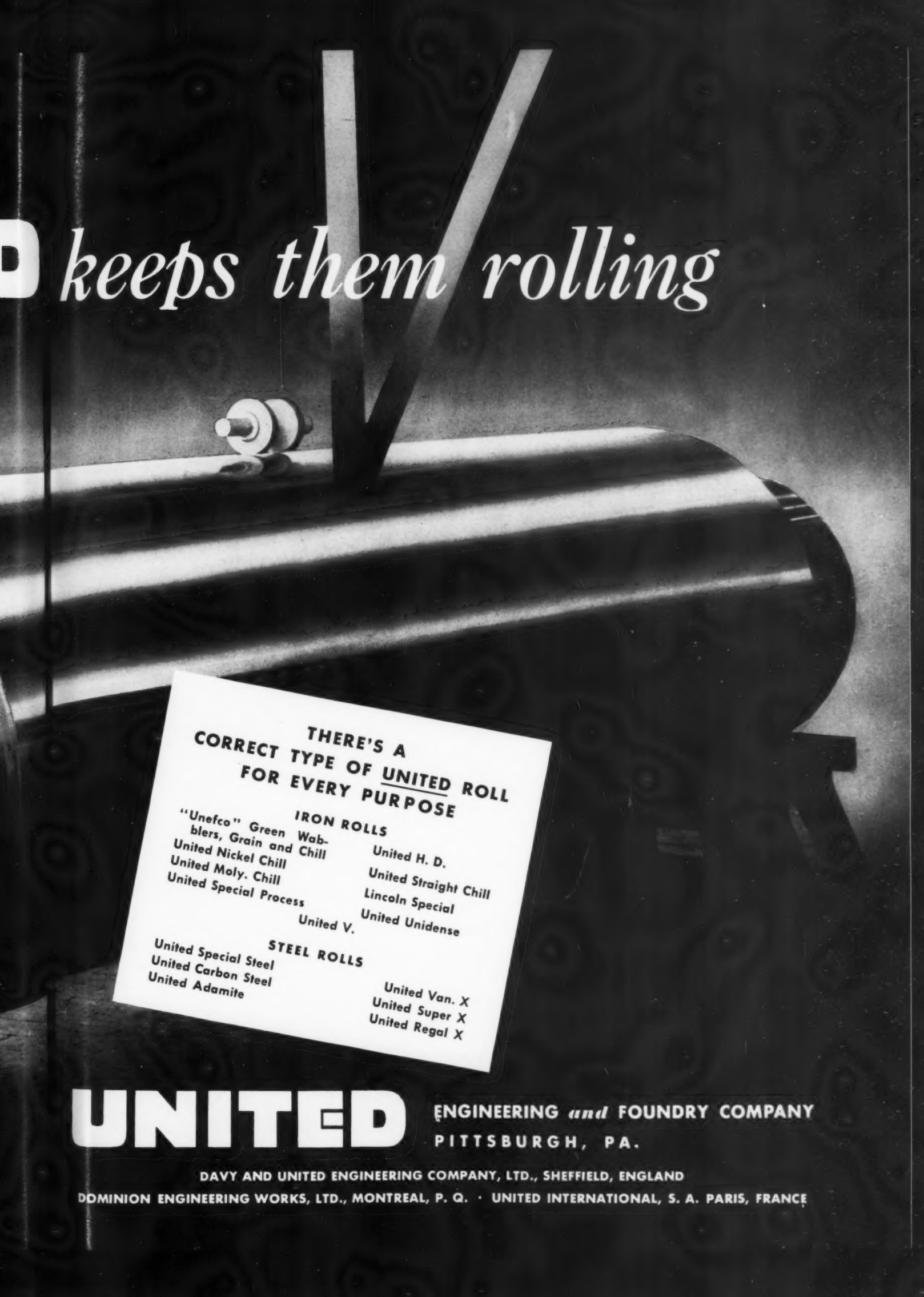
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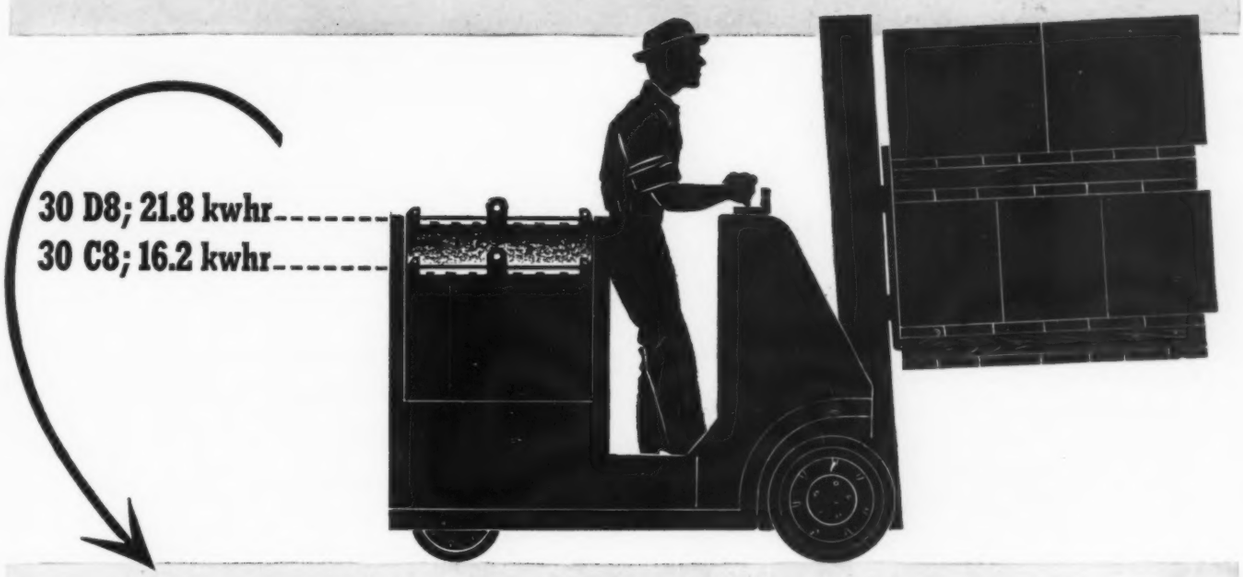

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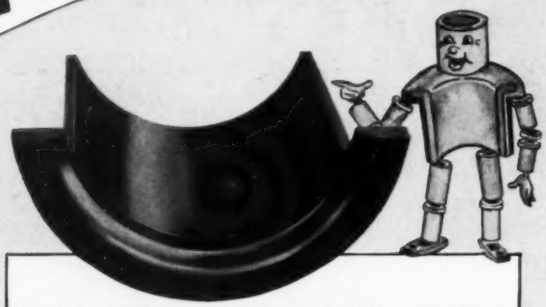

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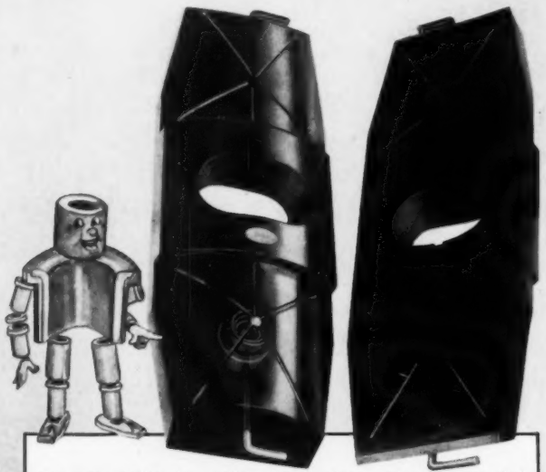

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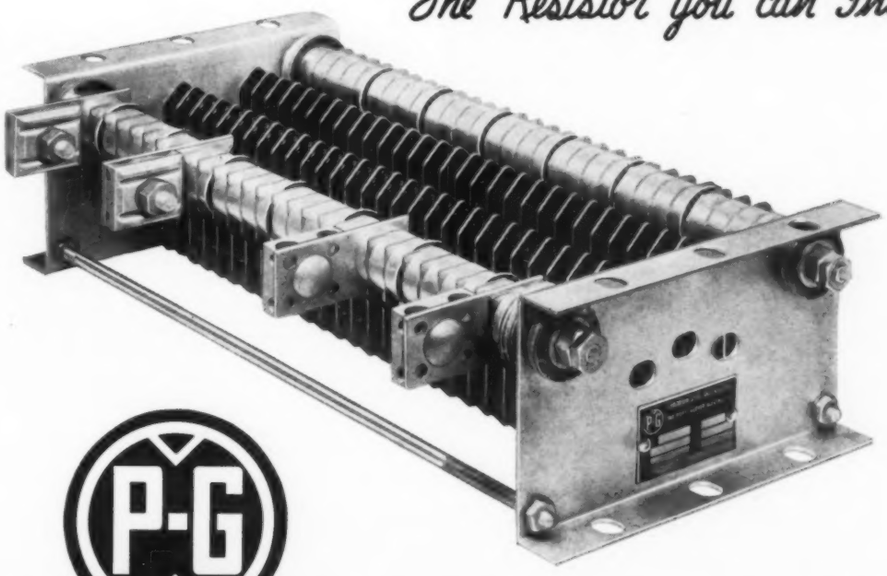

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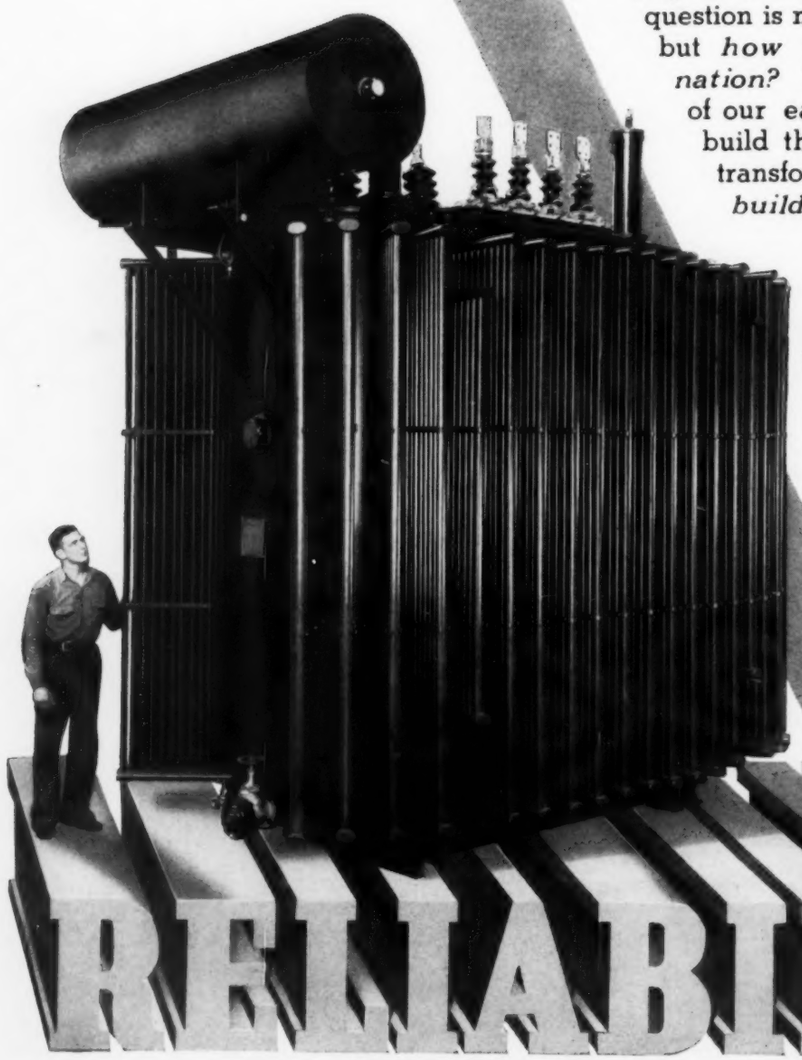

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RELIABILITY

1600 ENGINEERS HEAR W. T. BATT AT PITTSBURGH

To the more than 1600 engineers gathered at the annual banquet of the Engineers Society of Western Pennsylvania, in Pittsburgh, February 9, *W. T. Batt,* Director of Materials Division of the War Production Board, said that scrap metal, gathered in quantity and properly segregated and used, will provide the margin of victory over the Axis powers. He emphasized the responsibility of industry in the armament program, and stated non-essentials must be cut out if civilian demands show interference with supplies needed for war uses.

Mr. Batt is shown (upper right) with *J. K. B. Hare,* central district manager, Westinghouse Electric and Manufacturing Company, Pittsburgh, Pennsylvania. Among those in attendance were also *E. R. Weidlein,* director, Mellon Institute of Industrial Research, Pittsburgh, Pennsylvania, (center); *J. L. Campbell* and *S. H. Griffiths,* Ohio Steel Foundry Company, Lima, Ohio, (lower right); and *J. H. McElhinney,* assistant vice president, Wheeling Steel Corporation, Steubenville, Ohio, *J. E. N. Hume,* commercial vice president, General Electric Company, Schenectady, New York, and *Lorenz Iversen,* president, Mesta Machine Company, West Homestead, Pennsylvania, (below).

ITEMS OF INTEREST

Roy J. Wensley, formerly assistant general manager, I-T-E Circuit Breaker Company, Philadelphia, was recently appointed general manager of the I-T-E organization.

Mr. Wensley came to I-T-E in 1935 to take charge of all modernization projects in production of air circuit breakers and switchgear. He joined the staff in the period which marked the beginning of the broadening

ROY J. WENSLEY

use in industry of air-immersed protective apparatus

By 1935, Mr. Wensley had served some 18 years in engineering capacities at Westinghouse Electric and Manufacturing Company, principally with switchgear, refrigeration and electrical relays. His training fitted well with his work at I-T-E, and rapid progress was made. His original appointment in 1935 was assistant general manager, and the title was conferred as a part of a plan to have him assume the position of general manager in due course.

Wallace N. Guthrie has been elected executive vice-president and appointed general manager of the Cuno Engineering Corporation, Meriden, Connecticut. He has been with the company on a part time basis for the past year in connection with work now being done by Stevenson, Jordan and Harrison, Inc., New York, industrial and management engineers of which he is a partner. Mr. Guthrie, who attended Pratt Institute and is a graduate of the University of Pennsylvania, will now devote his full time to his new position.

E. K. Waldschmidt, formerly metallurgical contact man, Jones and Laughlin Steel Corporation, Pittsburgh, has joined the cold finished sales department of that company. Previous to metallurgical contact work, Mr. Waldschmidt was assistant metallurgist, Pittsburgh works, Jones and Laughlin, and for the past several years has been intimately associated with metallurgical work, both from the standpoint of plant operations as well as customer problems.

M. B. Antrim, formerly sales engineer, Steel Mill Division, Westinghouse Electric and Manufacturing Company, at Philadelphia, has joined Lukens Steel Company, Coatesville, Pennsylvania, as assistant to the electrical superintendent.

J. G. Green of Milwaukee, Wisconsin, has been made assistant general manager of the Storage Battery Division of Philco Corporation. Since January, 1940, Mr. Green has been assistant sales manager of the Louis Allis Company in Milwaukee, manufacturers of electric motors, where his duties brought him into contact with a representative cross section of industry throughout the country.

John R. Hoover has been appointed manager of synthetic sales of the B. F. Goodrich Company. Mr. Hoover succeeds **Dr. H. E. Fritz,** who was recently named company director of research. He had been manager of rubber-lined equipment sales since 1935 and is succeeded in that post by **Herman C. Klein,** who had been sales engineer in the department.

John A. Bigelow has been named plant protection engineer, Wickwire Spencer Steel Company, New York, and will supervise protection of the company's seven plants located in Buffalo, Worcester, Clinton and Palmer, Massachusetts; Mt. Wolf, Pennsylvania, and Blue Island, Illinois, including maintenance of employment records and employe identification.

W. A. Wirene has been appointed assistant sales manager of the Petroleum, Chemical, Mining, and Steel Mill section of the Industrial Department, General Electric Company.

Enos F. Bayrer, designer, Carnegie-Illinois Steel Corporation, died recently at his home in Gary, Indiana. Mr. Bayrer was educated in Southington, Connecticut, and entered the employ of the Hartford Machine Screw Company in Hartford in 1899. He then worked at the Stanley Works in New Britain, and in 1917 joined the United States Steel Corporation in Gary in the position he held at the time of his death. Mr. Bayrer had been an active member of the Association of Iron and Steel Engineers since 1938.

WANTED—Man with extensive experience to serve as assistant superintendent of blast furnaces in large steel company. Thirty-five to forty-five years of age with technical training preferred. State salary expected. Please send all replies to the attention of A—Iron and Steel Engineer, 1010 Empire Building, Pittsburgh, Pennsylvania.

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Hyatt Roller Bearings are used in land, sea and air fighting equipment . . . as well as in the machinery which helps build it . . . such as the vital operating equipment throughout America's mighty steel mills. Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey; Chicago, Detroit, Pittsburgh and San Francisco.

KEEP THEM GOING WITH HYATTS

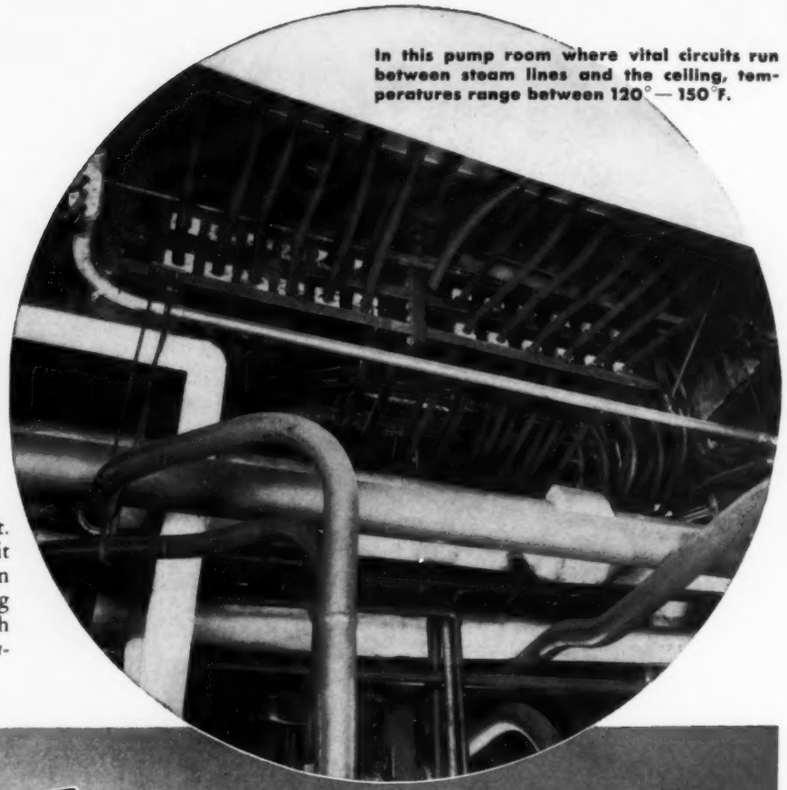
★ ★ ★ **HYATT** ★ ★ ★

ROLLER BEARINGS

QUIET

Installations like this →

If your plant has any power, control or lighting circuits keeping company with steam lines, boilers, furnaces, lehrs, soaking pits, or operating anywhere else under high temperatures — you'll have trouble sooner or later if the wire isn't *permanently insulated* against heat. You know what heat does to wire — it bakes ordinary insulation to a crisp — then comes failure, shut-downs and a rewiring job that could have been avoided with Rockbestos, *the wire with permanent insulation.*



In this pump room where vital circuits run between steam lines and the ceiling, temperatures range between 120° — 150° F.

Call for Insulation like this →

Rockbestos A.V.C. Power Cable (Underwriters' and National Electrical Code Type AVA) for locations where heat and moisture, oil, grease and corrosive fumes make trouble, has a maximum operating temperature of 110°C. (230°F.) because of these insulation features.*

1. Tough, rugged asbestos braid impregnated with inert compounds that insure positive protection against heat, flame, moisture, oil, grease and corrosive fumes.
2. Felted asbestos which serves as a heat-seal against high ambient temperatures.
3. High dielectric, moisture resistant, asbestos-sealed insert of lubricated varnished cambric.
4. Another felted asbestos wall which provides protection against conductor-heating overloads and copper-melting arcs.

* This type of insulation also used in lighting wire, control cable, motor lead cable and other Rockbestos A.V.C. constructions.

Plan now to prevent equipment outage and keep production moving with *permanently insulated* Rockbestos. Anticipate your minimum footage requirements and furnish preference rating forms when ordering. For a catalog showing many of the 118 standard constructions write to:

Rockbestos Products Corp., 833 Nicoll St., New Haven, Conn.

ROCKBESTOS A.V.C.

The Wire with Permanent Insulation

INLAND BUILDING TIN-SAVING UNITS

▲ Inland Steel Company, Chicago, has begun installation of an electrolytic tin coating plant at its Indiana Harbor Works. These new units will take care of the tin plating of approximately 2,000,000 base boxes of tin plate per year.

The new electrolytic process produces a very even coating of tin which is an important factor in the saving of this now precious metal. The new equipment is being installed to help overcome the threatened shortage of this metal. While some parts will be purchased from equipment manufacturers, the units will largely be constructed by Inland's own organization. The first unit is scheduled to be in operation by June 1, and the second unit about two months later.

In addition, and also as an aid in conserving tin, the company has contracted with the Wean Engineering Company for the manufacture of a bonderizing line for black plate for use in the canning industry. Manufacturers of cans expect to be able to use a considerable quantity of bonderized black plate which they will coat with protective lacquer. They expect that this bonderized black plate may be used for many applications as a substitute for tin plate. In some instances the ends of cans can be made of black plate even though it may be necessary to make the body of tin plate.

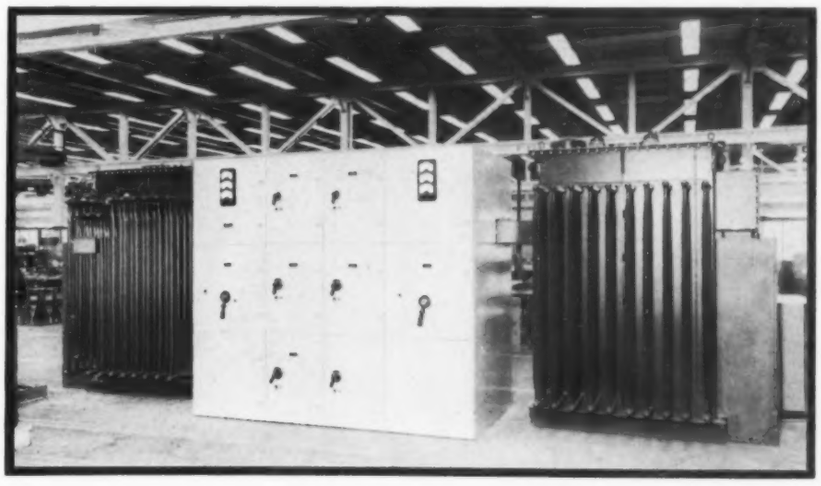
Through changes in manufacturing methods and with reasonable limitation of the uses of tin plate, Mr. Sykes, president of Inland Steel Company, stated that he believed that the manufacturers of cans will be able to provide for the essential needs of the country.

LOAD-CENTER POWER DISTRIBUTION SYSTEM

▲ Industry's rapid wartime expansion and the need for conserving strategic materials have given added significance to the substantial time and material savings and to the operating advantages made possible by the load-center form of power-distribution system applicable to industrial plants, shipyards, and naval and military projects. The application of this system universally in all expansions proposed and underway for 1942, it has been estimated, would mean that upwards of 5,000,000 pounds of copper and steel, largely in cable, could be diverted to other vital production requirements. The nature of the equipment also makes for speedier installation so that as far as power requirements are concerned, plants could get under way faster.

In load-center power distribution, power is distributed directly to the production area, or load center, and is there stepped down to the voltage at which it will be used. Short secondary cables then feed the power to motors, lamps, and other power utilizing equipment. Where the total power load of a plant or building exceeds about 1000 kva, several small load-center unit substations are used, distributed throughout the plant each near the center of its load area. This arrangement thus does away largely with the high cost and the voltage drop incidental to long, heavy low-voltage circuits.

A major advantage of the load-center system is its flexibility whereby it can be tailored to fit almost any application through the use of any one or combination of four basic circuit arrangements for a given plant: the simple radial system for plants where occasional service interruptions would not be serious; the primary selective system, which provides



The unit substation is a compact unit assembly of high and low voltage switchgear, and a step-down transformer.

for two sources of power supply, making available an alternate source, should a failure occur on one primary feeder; the secondary selective system, in which the load center has complementary branches, each permanently associated with a particular high-tension feeder; and the secondary network system, which utilizes permanently interconnected load-center units by means of low-tension tie circuits. Selecting the circuit arrangement to satisfy certain application requirements is largely a matter of balancing needed service reliability against installed cost.

The General Electric unit substation involved in the load-center distribution system is a compact unit assembly of a high-voltage switchgear section, step-down transformer section, and low-voltage switchgear section. The primary switchgear sections are of standard vertical-lift metal-clad construction with easily removable power circuit breakers. There is a full complement of instruments, meters, and relays. Primary equipment may be supplied for one or more incoming lines in ratings up to 15,000 volts and 2000 kva or higher.

The step-down transformer sections in the unit substations are specially designed three-phase units either of the noninflammable-insulating-liquid or air-cooled type. Primary and secondary leads are arranged for convenient throat connection direct to the switchgear sections. These unit substations step down the incoming high voltage of from 2300 to 13,800 volts to the utilization voltage of the plant served by the substation, which may be 120/208, 220, 440, or 550 volts. The units are available as standard in ratings up to 1000 kva at 120/208 or 220 volts and up to 2000 kva at 440 or 600 volts. Larger units can be furnished where the load requires, but even in cases of heavy load it may prove more economical to install two or more smaller units more conveniently located than the single larger one.

Secondary switchgear for the low-voltage distribution circuits is of the metal-enclosed drawout type with easily removable air circuit breakers designed for circuits of 600 volts or less, with breaker units of current ratings from 15 amperes up and interrupting ratings from 15,000 to 100,000 amperes as required. Both the high- and low-voltage switchgear sections are easily adaptable to extensions.

PRODUCES MOBILE GENERATING PLANTS

▲ Mobile generating plants are being produced by the Ready-Power Company, Detroit. These plants are complete central station power houses on wheels. They are available to industry, public utilities, governmental agencies and can be readily transported for instant power generation whenever needed.

Each mobile unit carries two 50 kw Ready-Power-International diesel engined electric plants, a switchboard, fuel oil storage tank, electric fuel transfer pump, lubricating oil rectifier, starting batteries, station transformer and both a-c and d-c station lighting system and, also, a substation with transformer, lightning arrestors and air break switches.

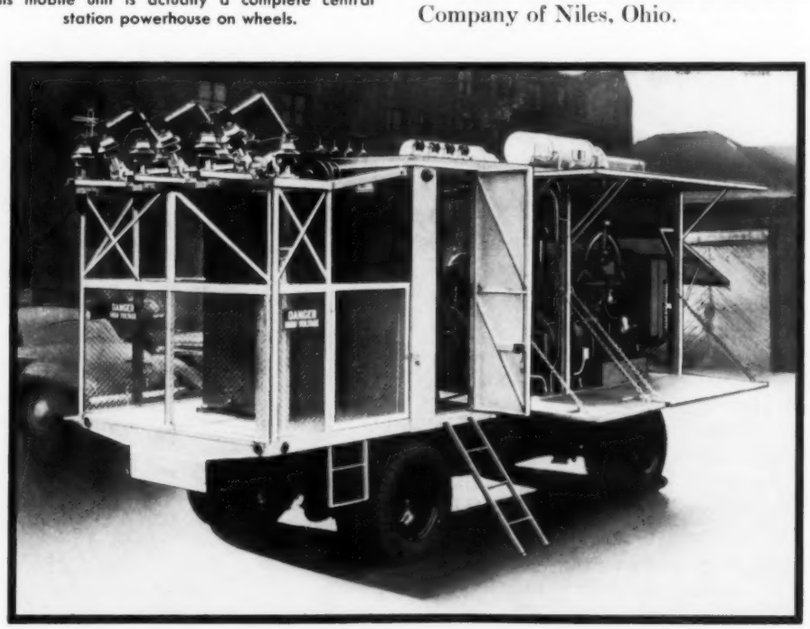
These mobile generating plants can be operated alone or in parallel with other mobile plants or as boosters in parallel with central station power. They carry their own fuel, have a power operated fuel supply pump for fuel transfer from tank wagon or other supply source. They are completely muffled and sound deadened and can be operated in congested districts without creating a noise nuisance.

The trailer design permits transportation at high speeds behind a tractor truck equipped for the operation of trailers with vacuum brakes. This mobility together with the self-contained completeness of these plants, makes possible not only rapid movement but also practically instantaneous "in service" operation.

The International Harvester diesel engines used in these mobile plants are started on gasoline with automotive type starting motor. After a brief warming-up period the engine is "thrown over" to full diesel operation. Starting is quick, and in case of battery failure, it is entirely practical to crank the engine by hand—a feature not found in other diesel engines and of utmost importance when used for emergency operation.

Ready-Power has issued Bulletin 522B which illustrates and describes these mobile generating plants. A copy of this bulletin will be sent on request.

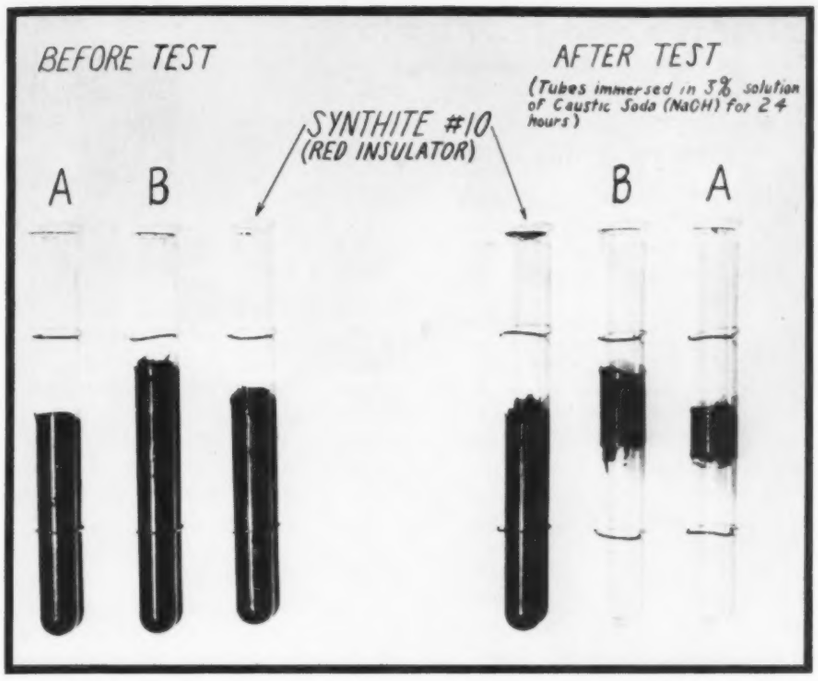
This mobile unit is actually a complete central station powerhouse on wheels.



REPUBLIC TO INSTALL MORE ARC FURNACES

▲ Republic Steel Corporation recently broke ground at its Chicago plant for the installation of six electric furnaces, each having a capacity of 70 tons. The annual capacity of the furnaces will be about 500,000 tons, and will raise Republic's electric furnace capacity to about 1,250,000 tons per year.

Contracts were also let for the construction of an 1100-ton blast furnace, at the company's Youngstown plant, to the Standard Boiler and Plate Iron Company of Niles, Ohio.



View showing enamel-coated test tubes before and after test for caustic resistance.

ENAMELS TESTED FOR CAUSTIC RESISTANCE

▲ The John C. Dolph Company laboratories recently conducted a series of tests to determine the caustic resistance properties of Dolph's Synthite No. 10 red insulator as compared with the similar resistance offered by other red enamels of their manufacture and a competitive product widely advertised as caustic resistant.

Glass test tubes were prepared with one dipped coat of each enamel represented in the test and baked at temperatures and hour cycles in strict accordance with manufacturers' instructions. The treated tubes were then submerged to about one-half of their length in a 3 per cent caustic solution, leaving a small portion of the enamel out of the solution. They were permitted to remain so for periods ranging from 12 to 24 hours.

The accompanying photograph illustrates the results of this test. Test tube A was treated with a Dolph enamel for which caustic resistance is not claimed. The caustic solution lifted this enamel film intact from the glass, an indication of poor caustic resistance.

Test tube B was treated with a competitive material for which caustic resistance is claimed. Examination of this tube revealed that the caustic had completely eaten away the film with the exception naturally of the ring of enamel at the upper end which did not come into contact with the solution.

The test tube treated with Synthite No. 10 red insulator was washed off with water after the test as were all tubes and examination revealed that the film had adhered tightly to the glass with the same degree of gloss as possessed before testing. The film showed no signs of deterioration or breaking down from caustic action.

Along with this remarkable resistance to caustic attack, Synthite No. 10 red insulator offers maximum resistance to the attack of acids and oil and water. Furnished at brushing consistency, it may be reduced 25 per cent with Dolph's No. 170 thinner or toluol for spray application.

Synthite No. 10 air dries dust free in ½ hour, tack free in 2 hours and hard in 8 hours. The caustic resistance of this material can be improved by baking treated units from 1 to 2 hours at about 200 F after air drying for 4 hours.

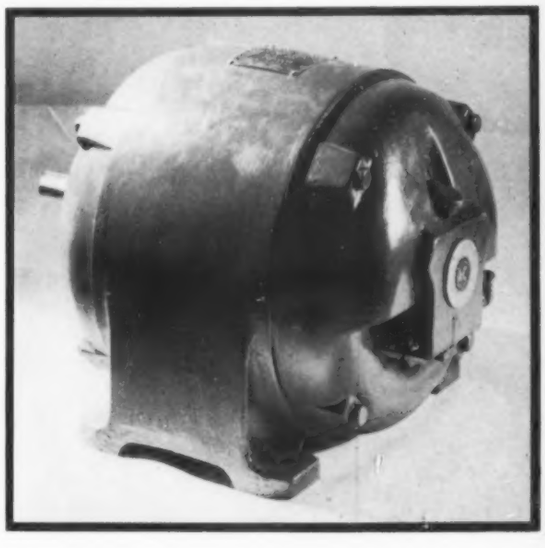
Synthite No. 10 is recommended for inside or outside use as a protective coating for rigid motor windings, commutator end bars or for any application where the use of a tough, high gloss, bright red enamel is desired. Synthite No. 10 red insulator may be obtained in 1 quart, 1 gallon, 5 gallon, 30 gallon and 55 gallon containers.

MOTOR DESIGNED FOR GREATER PROTECTION

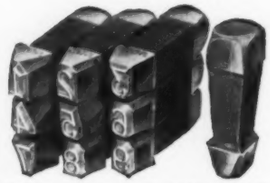
▲ "The greatest motor improvement in years" is how Allis-Chalmers describes the "safety-circle" protection of its new Lo-Maintenance motors. Specially developed to give the motor complete all-around protection, the "safety-circle" is a wide, solid rib—integrally cast as part of the frame—which forms an unbroken circle of protection around the stator.

All the experience of building motors for over fifty years has been concentrated in the development of this advanced product. One-piece cast frame and cast end-shields guard the motor from exterior knocks and abuse. A more liberal use of electrical materials makes this motor internally and electrically stronger because current and magnetic densities are less extreme. Improved bearing design delivers smoother performance with full-flow lubrication and easier maintenance. Additional cross strength has been built into the distortionless stator for maximum power efficiency.

The wide, solid rib, cast as part of the frame, forms a broken circle of protection around the stator of this motor.



SAFETY
WEDGE
GRIP



WEDGE GRIP LETTERS AND FIGURES

STAMPS and HOLDERS

- No Spalling! No Mushrooming!
- Deeper Impressions!
- Positive Grip!
- 50% to 100% More Service!

Wedge Grip Letters and Figures available with any size character 1/16" to 1" for prompt shipment.
Wedge Grip Holders made for all kinds of hot or cold markings including rough or semi-finished shell forgings, airplane and other machine parts.

Write for complete information

M. E. CUNNINGHAM CO. 105 E. Carson Street Pittsburgh, Pa.

WEDGE GRIP
HAND HOLDER

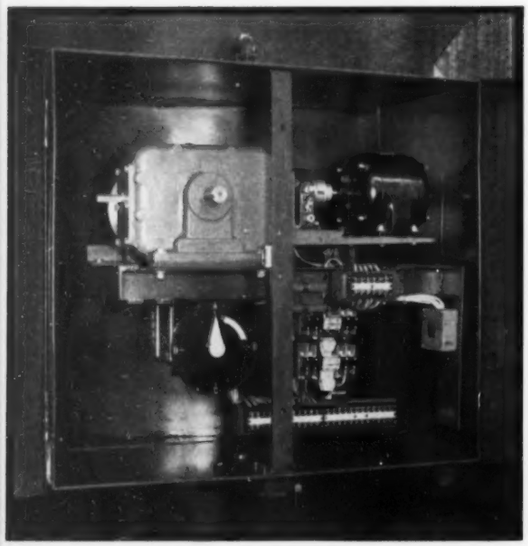
Rotor is keyed to the shaft for strength, and its outer surface is turned for smoothness and an accurate air-gap. Other Lo-Maintenance features are oil drains at bottom of bearings for easy flushing, removable end-pieces, and large conduit box for handy wiring.

NEW TAP-CHANGER HAS MANY SAFETY FEATURES

▲ Pennsylvania Transformer Company has developed a new motor operated no-load tap changer for furnace transformers, which incorporates many new safety features. This new tap changer is operated by remote control and is interlocked with an oil circuit breaker so that it cannot be operated while the transformer is energized. Compartment doors are also interlocked with the circuit breaker so that it is impossible to get into the compartment while the transformer is energized.

If the power supply to the motor fails, or is the motor windings should burn out, the tap changer can be operated manually by a crank which is furnished with a dial type position indicator which is visible through a glass window located in the compartment doors. For remote position indication, either a Selsyn type indicator is furnished, or individual pilot lights for various tap changer positions depending on what arrangement is most desired by the customer.

This remote control tap changer is interlocked with circuit breaker so as to be inoperable when the transformer is energized.



NEW WELDING ROD FOR CHARGING PEELS

▲ Resurfacing and maintenance of peels, the device used for charging steel scrap into open hearth furnaces, can be an almost endless job at terrific cost. Working in temperatures around 3000 F, lifting and rotating pans of scrap steel with total loads up to 5500 pounds, peels are subjected to extremely heavy abrasion. Wear is speeded by operating temperatures reaching up to 1400 F.

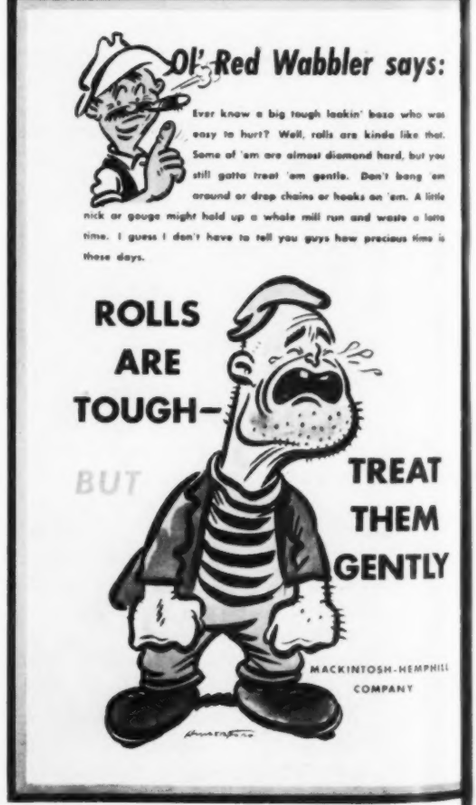
In recent open hearth service, it was found that peels resurfaced with "HCPF" welding electrodes gave from 4 to 8 times longer service. Where this maintenance operation had to be performed once or twice a week, the use of "HCPF" cut it down to about only once a month.

These findings typify the many new opportunities for improved welding results made possible by the rapid advancement in electrode manufacture. "HCPF", for example, a Harnishfeger product, is a special-purpose electrode of medium high-carbon steel with a machinable deposit having superior resistance to abrasion at high temperatures. Readers interested in obtaining procedures may do so by writing the Harnischfeger Corporation, Welding Division, Milwaukee.

POSTERS URGE CARE OF ROLLS

▲ A unique series of humorous posters outlining the fundamental "don'ts" in the care of rolling mill rolls is now being distributed free of

Posters of the type illustrated below do much to impress care of equipment upon plant personnel.


Ol' Red Wabbler says:
Ever know a big tough lookin' boze who was easy to hurt? Well, rolls are kinda like that. Some of 'em are almost diamond hard, but you still gotta treat 'em gentle. Don't bang 'em around or drop chains or hooks on 'em. A little nick or gouge might hold up a whole mill run and waste a lotta time. I guess I don't have to tell you guys how precious time is these days.
ROLLS ARE TOUGH—
BUT
TREAT THEM GENTLY
MACKINTOSH-HEMPHILL COMPANY

charge to roll users throughout the country by Mackintosh-Hemphill Company of Pittsburgh.

According to officials of the company, Mackintosh-Hemphill is producing the posters and offering them free of charge in the hope that they will contribute to the saving of time and vital materials during the wartime emergency.

The series, designed to be posted on plant bulletin boards, is not directed to management, but to mill operators themselves. Each poster is illustrated by Hungerford, famous Pittsburgh Post-Gazette editorial cartoonist, and represents the musings of "Ol' Red Wabbler," an imaginary old time mill operator.

The poster illustrated is the first of the series to be released, and according to reports, is being received with interest and enthusiasm far beyond early expectations. Company officials say that requests for additional posters are coming in at such a rate that it will be necessary to nearly double the number originally planned for distribution.

Besides being one of the country's manufacturers of rolling mill rolls, Mackintosh-Hemphill Company manufactures other rolling and steel mill equipment, various kinds of castings, and miscellaneous machinery such as shears, straighteners, saws, machine lathes, and hydraulic machinery.

RECORDS SET IN ORE PRODUCTION

▲ To meet the unprecedented requirements of the American war program, United States Steel Corporation subsidiaries have established a series of all-time records in the production and movement of iron ore and in the shipment of limestone and coal during the 1941 season.

The Oliver Iron Mining Company of Duluth, Minnesota, last year produced a record iron ore tonnage of 34,127,982 net tons compared with 26,193,055 net tons in 1940. Of this amount the vessels of Pittsburgh Steamship Company, United States Steel's Great Lakes subsidiary, brought to lower lake ports 23,542,751 gross tons of iron ore. In addition to this the Pittsburgh ships and other subsidiary vessels carried 7,418,607 tons of limestone and coal. These records were established between the period of April 4, 1941, when the first vessels left their winter berths, and December 12, 1941, when they closed their season.

The Pittsburgh Steamship Company's iron ore tonnage record compares with a movement of 18,713,382 gross tons in 1940 and exceeds the previous record year of 1916 by 3,900,222 gross tons. Of the total iron ore moved during the 1941 season on the Great Lakes (80,116,360 gross tons) the Pittsburgh Steamship Company alone was responsible for approximately 30 per cent.

To provide for a still greater movement in 1942, the Pittsburgh Steamship Company now has under construction five vessels which will be placed in operation sometime during the 1942 season.

Even in Winter Hot Spots Slow Up Production . .

TRUFLO CRANE CAB FANS
For cooling interiors of crane cabs and other confined areas. Adjustable both horizontally and vertically. Four blade type, 12 and 18 inch sizes.

Keep Workmen Cool with TRUFLO FANS

During even the coldest weather there are "hot spots" in many mills—places where heat and foul air play hob with production.

Truflo Fans can keep your men on their toes all year around. All Truflo Fans are designed and built to put fresh, cool air exactly where it is needed. Perfectly balanced blades give more air per h.p. . . . strong steel frames stand up longer under hard use . . . rugged wire guards protect men against injuries.

There is a type of Truflo Fan for every cooling and ventilating use. Write for literature on any of the following kinds:

PORTABLE COOLING FANS
CRANE CAB FANS • WALL FANS
EXHAUST FANS • BLOWERS
ROOF VENTILATING FANS
PENT HOUSE FANS

TRUFLO PORTABLE COOLING FANS
Easily portable. Help keep efficiency high where work is hottest. 12 to 36 inch diameters.

TRUFLO FAN COMPANY
554 MAIN ST., HARMONY, PA.

CORRECTION

In the list, "Electric Motors Over 300 Horsepower", published on page 46, IRON AND STEEL ENGINEER, January, 1942, one item was omitted: One 1000 hp, 250-750 rpm, 600 volt d-c motor, driving a Steckel mill at Allegheny-Ludlum Steel Corporation, West Leechburg, Pennsylvania; manufactured by General Electric Company.

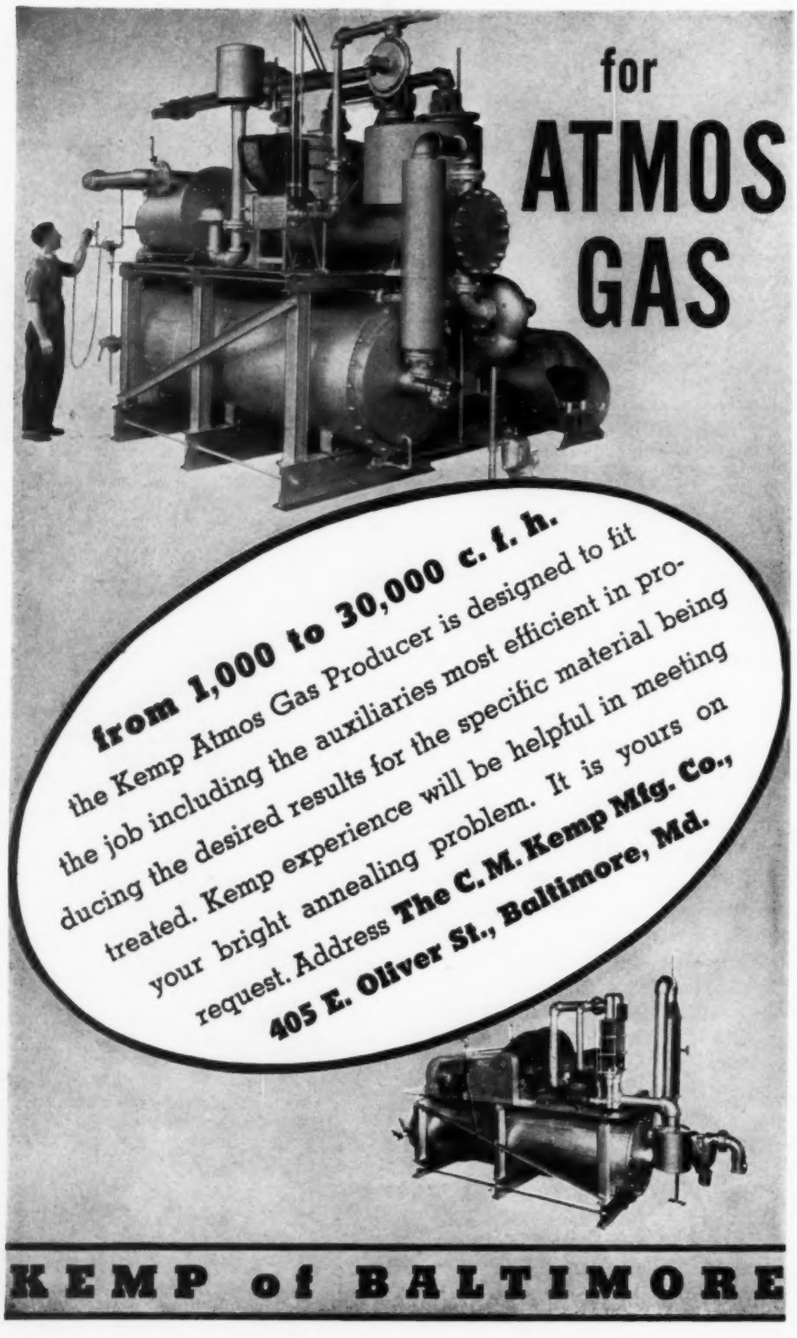
LUKENS TO EXPAND PLANT FACILITIES

▲ The United States Navy Department will spend nearly $20,000,000 for additional facilities and plants at Lukens Steel Company and its subsidiary, By-Products Steel Corporation, it was announced by Robert W. Wolcott, president of Lukens Steel Company.

At By-Products Steel Corporation, a new flame-cutting plant, 90 ft x 350 ft, costing approximately $800,000, will be constructed by the Navy, and be rented to and operated by this Lukens subidiary.

At Lukens Steel Company, the Navy will expend $18,909,600. Additional facilities for handling and shipping rolled armor plate will be constructed. A new 120 in. finishing mill will be installed behind the present Lukens 112 in. mill. Additional facilities will be installed in the Lukens No. 3 open hearth steel-making plant. In addition, an armor plate heat-treating plant will be built. Arthur G. McKee & Company, steel mill engineers and constructors of Cleveland, will handle all the engineering and construction work.

At the present time, Lukens rolls the widest, heaviest and thickest rolled armor plate produced in this country.


for
ATMOS
GAS
from 1,000 to 30,000 c. f. h.
the Kemp Atmos Gas Producer is designed to fit the job including the auxiliaries most efficient in producing the desired results for the specific material being treated. Kemp experience will be helpful in meeting your bright annealing problem. It is yours on request. Address The C. M. Kemp Mfg. Co., 405 E. Oliver St., Baltimore, Md.
KEMP of BALTIMORE

ELECTROLYTIC TIN USE EXPANDING

▲ To aid in conserving the nation's vital supply of pig tin, and to help in meeting can makers' war time demands, United States Steel Corporation subsidiaries are installing three additional electrolytic tin plating production lines and six supplemental production lines for chemically treating black plate, it was recently announced by Benjamin F. Fairless, President of United States Steel Corporation. Both the electrolytic tin plate and chemically treated black plate will, in certain applications, be used as a substitute for hot dip tin plate.

These new facilities which will be built by the Wean Engineering Co., Inc., of Warren, Ohio, and cost about five and one-half million dollars are to be located in subsidiary plants in the Chicago, Pittsburgh, and Birmingham districts. One electrolytic tin plate line and two black plate treatment lines will be installed in each district.

The new lines for the production of the electrolytic tin plate will have a total annual capacity of approximately 225,000 tons which tonnage under normal conditions would require the use of 3,375 tons of pig tin by the conventional hot dip method compared with 1,125 tons under the new process.

These facilities, to be completed as

soon as possible, will supplement the original installation of an electrolytic line at the Gary Tin Mill where the first such equipment of its kind in the world was placed in operation. Also the first of its kind, the Gary black plate chemical treatment line was installed last year. Since the time of the early installations, comprehensive tests and experiments have proven the success of both these technical developments.

Electrolytic tin plate is produced by coating black plate with tin by means of an electric current passing through a solution, rather than by the conventional dipping of black plate into molten tin. The electrolytically coated product of United States Steel Corporation subsidiaries is known as Ferrostan and has been used for a variety of purposes.

BOOKLET DESCRIBES RAIL CLAMP LINE

▲ The Robins Conveying Belt Company has just published a twenty-page profusely illustrated booklet (bulletin No. 114) describing the complete line of Robins (Mead-Morrison) rail clamps. Due to their comprehensive experience extending over many years as manufacturers of the various types of movable structures which rail clamps are designed to safeguard, the Robins company has been in a position uniquely favorable to the development of these devices.

Bulletin No. 114 cotains a full description of each of the five different types of single and double, manually operated and automatic rail clamps. These range from a small manually operated single rail grip for certain types of light towers and gantry cranes having worm drives, to the large patented automatic self-adjusting and self-tightening double rail clamps which in actual shop tests have resisted horizontal forces of considerably over 100 tons.

A notable feature of most Robins (Mead-Morrison) rail clamps is the self-adjusting arrangement which permits the clamp to automatically adjust itself to properly grip any variation of rail head width within a range of ½ in. This self-adjusting feature also compensates for wear in the clamp shoes, pins, etc., and results in a minimum of maintenance and adjustment. In the double rail clamp, the self-adjusting feature has a further advantage. Regardless of inequalities in the width of rail heads at the clamp, both rails are gripped with full power and the resistance to movement is fully equalized on both rails.

The outstanding feature of these rail clamps, found in all models excepting type "A", is the patented self-tightening arrangement. By means of a rotating concentric cam and wedge-shaped shoe, the rail is clamped tighter and tighter as wind pressure increases.

Anemometer equipment is also fully described in Robins bulletin No. 114. The effect of anemometer installations is to make it impossible for the operator to move the structure once the wind has attained a certain predetermined velocity.

The new bulletin also includes numerous illustrations and sketches of various types of movable structures such as ore and coal handling bridges and unloading towers manufactured by Robins Conveying Belt Company. A copy of bulletin No. 114 may be

CONDULETS
MANUFACTURED ONLY BY
CROUSE-HINDS
Three of the outstanding reasons why **Condulets** do a better job are—
① **FERALOY METAL**—Strong and Lasting
② **TAPER TAPPING**—A Secure Joint
③ **FINISH**—Three Separate Protective Coats

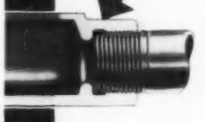
② TAPER TAPPING

The superiority of Crouse-Hinds taper tapped Condulets is well illustrated in these photographs showing sections of conduit fitting hubs.

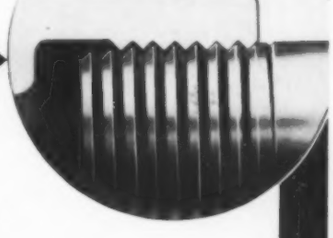
The only way taper-threaded conduit can be made tight in a straight tapped hub is by bottoming the conduit against the integral bushing —

or jamming the conduit on the last threads.

Either way usually leaves the cover opening in a wrong position — backing up to proper position loosens joint.



STRAIGHT TAPPING WRONG WAY



CONDULETS are always taper tapped

TAPER TAPPING RIGHT WAY

CONDULET

The threads on the conduit bear against every thread in the hub. See how much more area there is in these engaging surfaces than in the method shown above.

They won't loosen under vibration. They make and maintain an excellent metal to metal contact, which must be had for the continuous ground required to make the conduit system safe.

Because of taper tapping, CONDULET cover openings can be faced in the required direction and remain tight on the conduit

CONDULETS—The Standard of Quality in the field of electrical conduit fittings.

A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

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CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

obtained without charge by writing to Robins Conveying Belt Company, Passaic, New Jersey.

IRON MEN AND THEIR DOGS

▲ Recounting one hundred years of industrial activity, Koppers Company, Bartlett-Hayward Division, has published a 225 page cloth-bound book entitled "Iron Men and Their Dogs". Although essentially a history of the Bartlett-Hayward Division from their origin in 1837 as Hayward and Friend, Stovemakers, the book gives many interesting sidelights on early industrial Baltimore, and on the traditional Baltimorean sport of duck shooting. Though seemingly an incongruous mixture, duck shooting is romantically interwoven with the business history, and is the basis of the two huge cast iron dogs which mark the entrance of the division office in Baltimore, and which have served as talismans for the enterprise throughout its progress.

BETTER RESULTS IN FURNACE OPERATION with HAYS INSTRUMENTS

SUPERSENSITIVE DRAFT RECORDERS SERIES "OT" You can make sure of BALANCED Draft Conditions in Open Hearths, Soaking Pits, Annealing Furnaces and Slag Mills by installing Hays Series OT Recorders.

These instruments give a correct indication of furnace atmospheres and a permanent record of pressures and drafts at vital points as guides for most effective operation.

Write for descriptive bulletin.

PATENTS PENDING. This gage is calibrated in terms of air and gas flow—but may be used for any two flows for which the instrument is calibrated.

HAYS VISIO-RATIO GAGE

3 INSTRUMENTS IN 1 . . . 1. Air-Flow Indicator . . . 2. Fuel-Flow Indicator . . . 3. Ratio Indicator. Shows at a glance the exact ratio existing between flow of gas or flow of oil or other measurable fluid: pressure, draft, suction, temperature (up to 1000° F.) speed in R.P.M. or inches per minute, position, level and others.

This newest Hays instrument is a guide to higher manufacturing efficiency, increased production, better products and lower costs. It shows relations at a glance and eliminates the necessity of making calculations to determine excess or deficiency.

If you will write us, stating the conditions, we will tell you exactly how the Hays Visio-Ratio Gage can be applied to your problem.

The HAYS CORPORATION
SINCE 1901 COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

SWITCH FOR CONTROL OF CIRCUIT BREAKERS

▲ A new double-break, direct-acting rotary switch for the control of circuit breakers has been developed by the Roller-Smith Company, Bethlehem, Pennsylvania. The switches are insulated for 600 volts and have a continuous current carrying capacity of 10 amperes.

This switch is built up of units, each unit consisting of two single break contacts connected in series by means of a jumper. The switch has a spring return arrangement so that when the handle is released the switch returns to the off position, opening the contacts. The handle is of the pistol grip type, facilitating operation of the switch.

A red and green target is furnished as a part of each switch to indicate the last position of the switch. For example, to operate the circuit breaker control switch in conjunction with indicating lamps, the switch is turned to the close position, 45 degrees clockwise. This operation closes the breaker and energizes the red lamp through a breaker auxiliary switch. When the handle is released, the spring return feature causes the switch to return to the off position, opening the contacts. The red target shows that the last position was to close the breaker.

To trip the breaker, the switch is turned to the trip position, 45 degrees counter-clockwise. This brings up the green indicator and lights the green lamp through another auxiliary switch.

If the breaker trips by some means other than by the switch the green lamp and the red target are seen at the same time. This indicates that the breaker tripped on some fault.

TRAILER CARRIES WELDING MACHINE

▲ A new two-wheeled, lightweight, pneumatic-tired trailer for mounting 200, 300, 400 ampere Hobart electric drive welders is now in regular production at Hobart Brothers Company, manufacturers of arc welding equipment, Troy, Ohio. Designed for road towing up to 35 miles per hour, this unit will prove very useful for hurry-up trips to different locations for emergency production, maintenance, and repair work. Trailer is so

designed that mounting it is accomplished easily by means of three bolts in frame of trailer which register with three holes in the legs of the welding machine. Combination tow bar and standing support has a hand-operated ratchet for locking support arm in position. Unit is easily moved by hand by virtue of its low, underslung construction; narrow tread; and precision method of balancing. This all arc welded steel trailer is capable of trailing over very rough terrain. Measures 54 in. long, 45 in. wide, 27 in. high (over tires); 13 in. axle center. Tires are 16 x 5.50, 4 ply.

NEW LITERATURE

▲ Four completely new series of alloy steels designed to make the nation's limited reserves of strategic metals go further and help build more guns, tanks, battleships and airplanes were announced by the American Iron and Steel Institute.

In making the new steels, producers will use less virgin chromium and nickel, and more of these alloys in the form of scrap recovered from steel previously produced.

Details of new steels are announced in a booklet entitled, "Possible Alternates for Nickel, Chromium and Chromium-Nickel Constructional Alloy Steels." The booklet was prepared at the request of the Office of Production Management, which has been succeeded by the War Production Board.

To develop the series of new steels, a group of metallurgists chosen from technical committees of the Institute, the Society of Automotive Engineers, and from alloy manufacturing companies, devised hitherto untried chemical compositions, melted experimental heats of the new steels, tested them thoroughly and selected those which seemed suitable.

The placing of priority orders on nickel and chromium, because sufficient supplies were not available, made it necessary to develop suitable alternates. Those presented in the booklet embrace a series of carbon-molybdenum steels, manganese-molybdenum-steels, and also low chromium-molybdenum and low nickel-chromium-molybdenum steels.

The use of the alternate steels, the booklet states, may make necessary some changes in established methods of fabrication or heat treatment procedures, or both, or may even make necessary some changes in engineering design of the product affected.

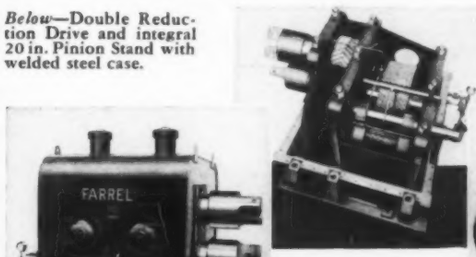
▲ Bulletin 411-CT describing and illustrating the Jefferson line of control, indoor type power circuit, door bell, chime and signaling transformers has just been published by Jefferson Electric Company, Bellwood, Illinois. The bulletin is sectionalized and complete electrical and dimensional data included to assist in simplifying the proper selection of transformers for various applications.

▲ Catalog No. 80, a 32-page, 8½x11 booklet, has just been issued by the Eclipse Air Brush Company, 400 Park Avenue, Newark, N. J. It covers their complete line of spray equipment for both manual and automatic operation, in addition to their Pneumix air motored agitators for all mixing jobs in batches up to 200 gallons.

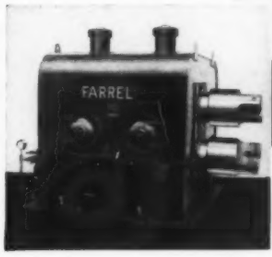
FARREL GEAR DRIVES *and* PINION STANDS

Adaptable to Individual Operating Conditions

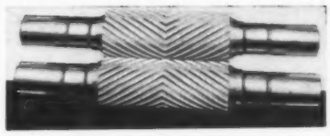
Below—Double Reduction Drive and integral 20 in. Pinion Stand with welded steel case.



Below—4000 HP Pinion Stand for four-high reversing cold strip finishing mill.



Above—Cover removed to show gears and interior construction of Drive at left.



Above—Farrel-Sykes Continuous Tooth Herringbone Rolling Mill Pinions are precision generated for smooth, quiet operation.

Farrel Heavy Duty Rolling Mill Drives and Pinion Stands are adaptable by design and construction to individual conditions of operation. For example, the beds may be cast steel or Meehanite or welded steel construction. Dependent upon load conditions and the requirements for rigidity a double-walled or single-walled deep base may be used. Bearings may be either plain babbit-lined steel cartridges or any approved make of anti-friction bearing.

While gears and pinions are usually continuous-tooth herringbone, accurately generated by the Farrel-Sykes process, either single helical or a combination of single and double helical gears can be furnished. As conditions demand, lubrication may be by dip and splash system, by pump built into the unit and driven by one of the shafts, or by separate lubrication system.

The high precision with which Farrel Mill Drives and Pinion Stands are made assures smooth, quiet operation, and their rugged construction enables them to withstand the stresses, shocks and wear incident to the high speeds and heavy loads of modern mill practice.

When you have a gear problem call in a Farrel gear engineer for consultation.

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

The introductory section of the catalog outlines the reasons for the low pressure principle under which all Eclipse spray equipment operates.

This free-on-request booklet is illustrated with many pictures of the equipment in operation on various types of work.

▲ At exceptionally low cost, the industrial steam plant can now have dependable protection against damage caused by contaminated condensate, by using Leeds & Northrup's new signalling controller.

Used where indicating and recording of condensate purity are not needed, this simple, automatic equipment tests condensate purity continuously. Its self-contained signal lights show whether condensate is above a specified minimum purity and is safe to use again, or whether it is below this limit and should be diverted to waste.

In addition, the instrument can operate external warning bells or lights. Or, it can provide automatic two-position control by regulating a motor-driven valve in the condensate line to dump impure condensate.

If the operator wishes to measure condensate resistance, he can do so by turning the instrument's control-setting dial until both signal lights are out, and reading the dial scale.

An 8-page catalog describing this equipment has just been issued. To receive a copy, ask Leeds & Northrup Company, 4934 Stenton Avenue, Philadelphia, Pa., for Catalog N-95-163(1), "Simplified Signalling Controller for Automatic Testing of Condensate Purity".

▲ The Trumbull Electric Manufacturing Company of Plainville, Connecticut, is distributing circular No. 335 illustrating and describing their new type L.V.D. (low voltage drop) Buss-Wa, which delivers full voltage power at the point of load. This Buss-Wa—an enclosed busbar main artery of an electrical feeder distribution system—is so engineered and constructed that it will easily withstand the heavy short circuit stresses that may be encountered in modern electrical distribution systems. The L.V.D. Buss-Wa goes far beyond the mere consideration of transmission of electrical current and cross sectional area of conductors into the field of high interrupting capacity, which insures consistency of selection with feeder protective devices of like high interrupting rating. Circular No. 335 will be sent gladly on request.

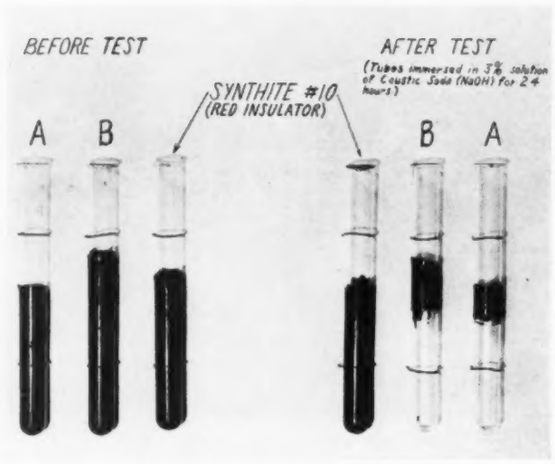
▲ A timely and interesting folder entitled "Plant Protection Begins with Floodlighting" has just been released by the Goodrich Electric Company. Dealing with the present and urgent need for protective lighting around industrial plants, this folder illustrates the various styles of porcelain enameled floodlights available to meet the demands for illumination in different locations. All equipment listed are in accordance with FBI specifications.

In addition to many popular styles of permanent and portable floodlights, the folder also introduces a new fixture known as the Elipso Standlite, designed for high intensity and sharply defined lighting around property lines without illuminating buildings and grounds.

Copies of the folder may be obtained by writing the Goodrich Electric Company, 4600 Belle Plaine

YOU CAN PROTECT MOTORS AGAINST CORROSIVES

Here's Proof---



This test was run to determine the caustic resistance of DOLPH'S SYNTHITE No. 10 Red Insulator and two other red oilproof enamels. One coat of each enamel tested was applied to a glass tube, all tubes baked and immersed in a 3% caustic solution for 24 hours. Two enamels broke down completely—their film eaten away by caustic.

SYNTHITE No. 10 did not show signs of deterioration but adhered tightly to the glass, retaining its high gloss.

SYNTHITE No. 10 also offers maximum resistance to acids, oil and water. It may be brushed or sprayed, dries quickly and is recommended for use on rigid motor windings, commutator end bars, or for any interior or exterior use when a tough, high gloss, red finish is desired.

Write today for further information.

Dolphs

JOHN C. DOLPH COMPANY

Insulating Varnish Specialists

166A EMMETT ST. NEWARK, N. J.

Avenue, Chicago, Illinois. Ask for folder No. 101.

▲ A new catalog describes Gatke moulded fabric bearings of various types for grease or oil lubrication, water lubrication, acid-resisting service, and some unlubricated applications. Included are operating characteristics of the various types with performance results on typical applications. Furnished promptly on request to the Gatke Corporation, 228 North La Salle Street, Chicago.

▲ The Electric Controller and Manufacturing Company, Cleveland, Ohio, has issued a new booklet, No. 930, on frequency relay magnetic crane control. Two new systems of control for a-c cranes are described: the E C & M A-c Dynamic Lowering Control and the E C & M Contra-torque Lowering Control. Made possible by the E C & M frequency relay, these control systems produce results previously unattainable on a-c wound rotor motored equipment. The booklet is available upon request to the company.

▲ Publication GED-650B, just issued by the General Electric Company, lists the complete line of G-E electric heaters, heating devices, and heat control equipment. Each item in the line is pictured, and many are accompanied by a list of applications as well as by installation and operation data.

Many photographs show interesting jobs being done by electric heaters in industry. Information useful in calculating power requirements, a tabulated list of uses for G-E electric furnaces, and a list of G-E industrial heating publications round out the catalog.

▲ Cochrane Corporation, Philadelphia, has announced a four-page bulletin covering the new Chochrane-Becker high-pressure condensate return system. Fifty different industries are listed in which appreciable increases in production rates and excellent fuel savings are being made by the use of this unit in draining jacketed kettles, drying rolls, coil cookers, dryers, unit heaters, laundry and platen presses, and similar equipment that depends on uniformly high steam temperatures for efficient operation.

A typical installation is described in detail with a four-color illustration showing steam, condensate, and makeup lines. A similar drawing illustrates the operation of the jet-loop principle on which the system operates. Detailed engineering specifications cover the technical features of design and construction.

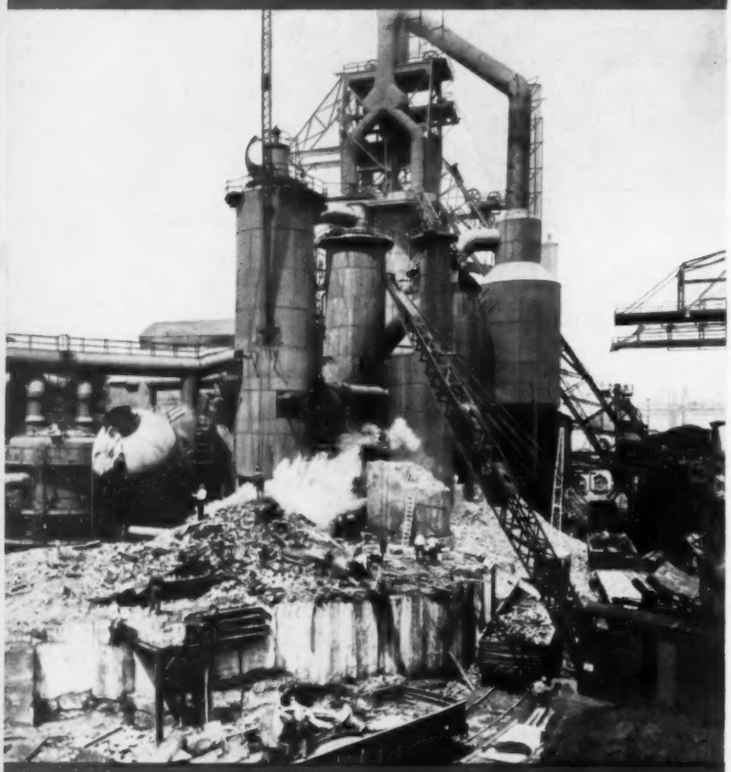
Copies of this new bulletin may be secured from Cochrane Corporation, Philadelphia, Pennsylvania, by requesting publication 3025.

▲ The Ideal Commutator Dresser Company Catalog-Handbook which has taken two years to complete includes 52 pages of recommendations, application data, photos and engineering information. It gives a quick index source of reference for complete data on Ideal variable speed pulleys, Ideal variable speed transmissions, Ideal automatic tension control motor base. Gives sizes, rated capacities, design and operating details, where applicable, how installed, etc.

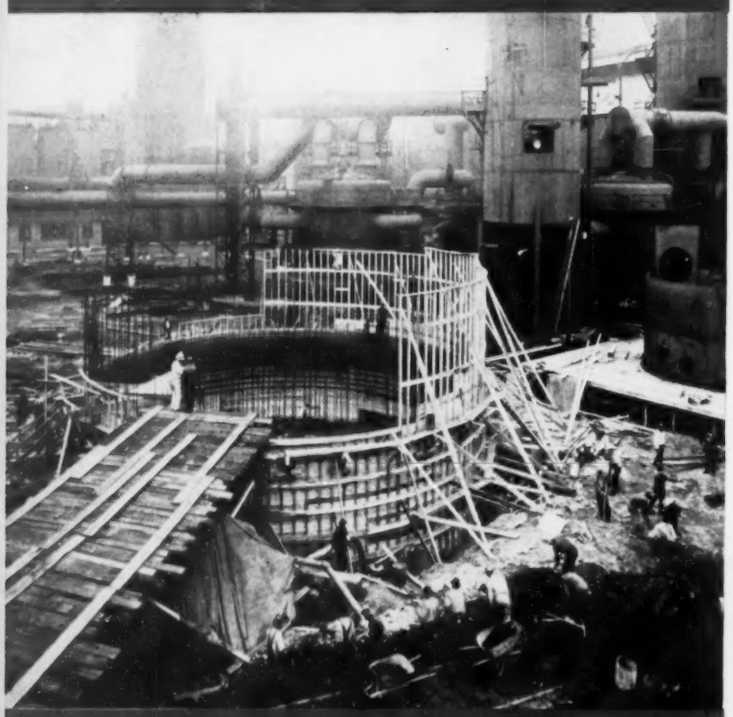
A free copy is available to design engineers, mechanics, superintendents, purchasing agents, consulting engineers, and others interested in variable speed transmission equipment, upon application to the manufacturer.

AMCO
FURNACES
Front view of AMCO Rotary Hearth Furnace, including control panelboard, for heating all sizes of billets for shell forging.
OVER A QUARTER-CENTURY OF ENGINEERING PROGRESS
...are doing their part in America's Victory Program
AMCO Heavy Duty Furnace for large forgings; fired with Pulverized Coal; automatically controlled.
AMCO Continuous Charging-end-fired Slab-heating Furnace combined with AMCO Recuperator.
• The remarkable comparative production records being compiled by AMCO Ordnance Furnaces are truly significant. They mean that AMCO builds these furnaces up to the standard of its regular commercial equipment and not merely for a "quick turnover."
The new AMCO Principle and Method of "Artificial Loading" increases the efficiency, production and uniformity of all batch-type furnaces. Guns, tanks, armor-plate and other ordnance furnaces may be improved with this new AMCO principle.
If you are confronted with variables and losses due to non-uniform heating, put it up to AMCO!
The AMSLER-MORTON Company
FULTON BUILDING · PITTSBURGH PA.

McKee *again* increases iron and steel



Dismantling existing furnace in preparation for reconstruction



Building furnace foundation and beginning of stove construction.

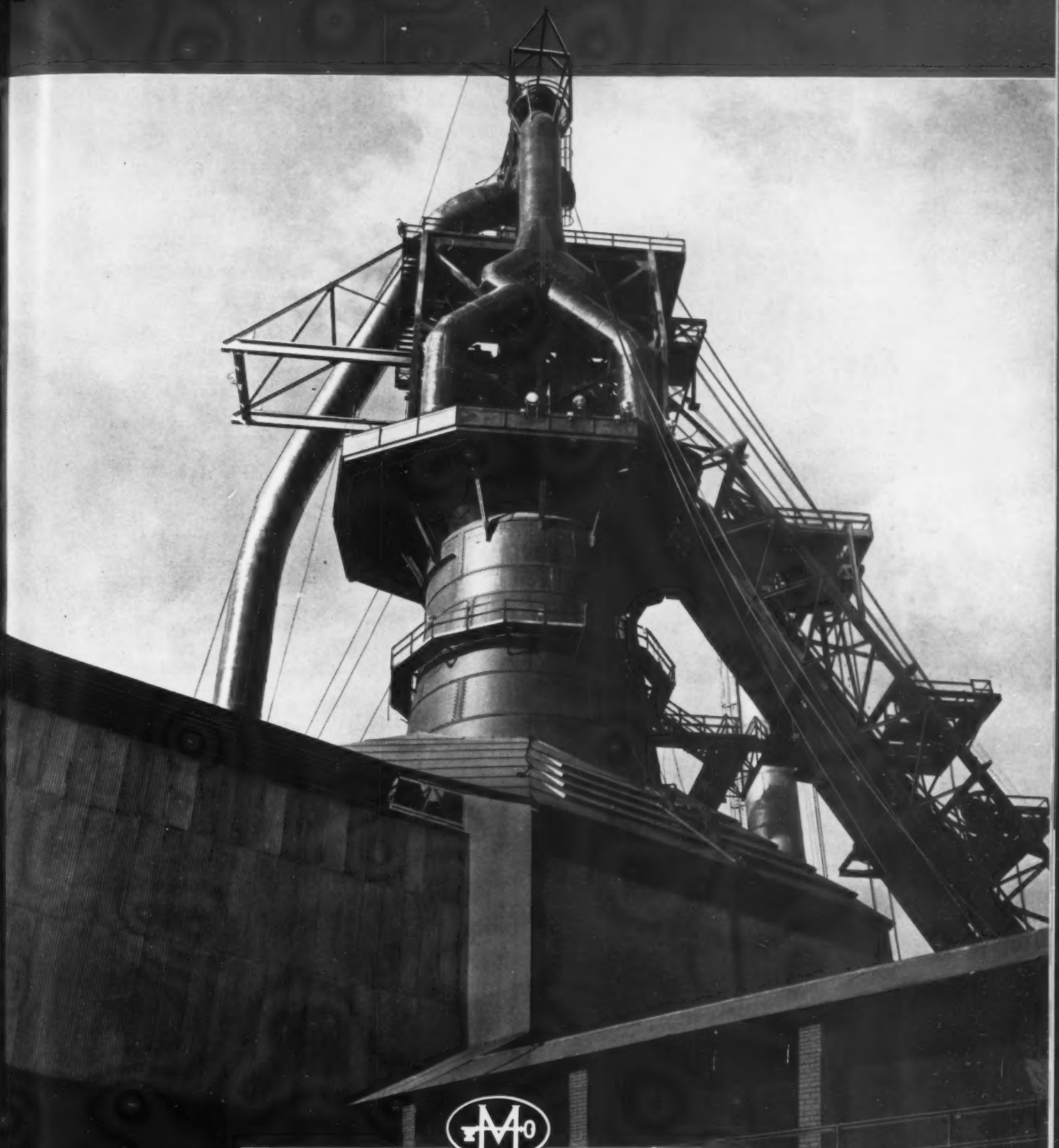
WAR has now imposed on the Iron and Steel Industry new and greater demands than ever before for material for guns, ships, tanks and other armaments.

To produce the enormous quantities of steel needed, iron and steel companies throughout the United States and Canada have increased and are still increasing plant capacities. Side by side with them, Arthur G. McKee & Company are playing a major role in providing the vast, new production facilities which now form the very base of the nation's war effort.

Shown in various stages of construction in the accompanying photographs is another blast furnace recently completed by the McKee organization. This is one of many projects completed by McKee during the defense program to insure an increased and uninterrupted production of iron and steel to fight America's battles.

Erecting furnace and stoves.

plant capacity for America's Defense



Completing construction of furnace.

Arthur G. McKee & Company

★ *Engineers and Contractors* ★

2300 CHESTER AVENUE • CLEVELAND, OHIO

ROCKEFELLER PLAZA
NEW YORK, N. Y.

COMMERCE BUILDING
HOUSTON, TEXAS

FOR HIGH VOLTAGE CIRCUITS USE WIRES AND CABLES INSULATED WITH OKOLITE

Specifications

For operation up to 35,000 volts at 70°—75° C. copper temperature. Sizes #14 to 2,000,000 CM. Single and multiple conductor cable designs available with metallic, non-metallic, synthetic or fibrous protective coverings.

Write for Booklet OK 2007-A

OBTAIN THESE ADVANTAGES

- greater moisture, ozone and heat resistance
- greater current carrying capacity
- higher breakdown voltages
- lower power factor
- more stable electrical characteristics

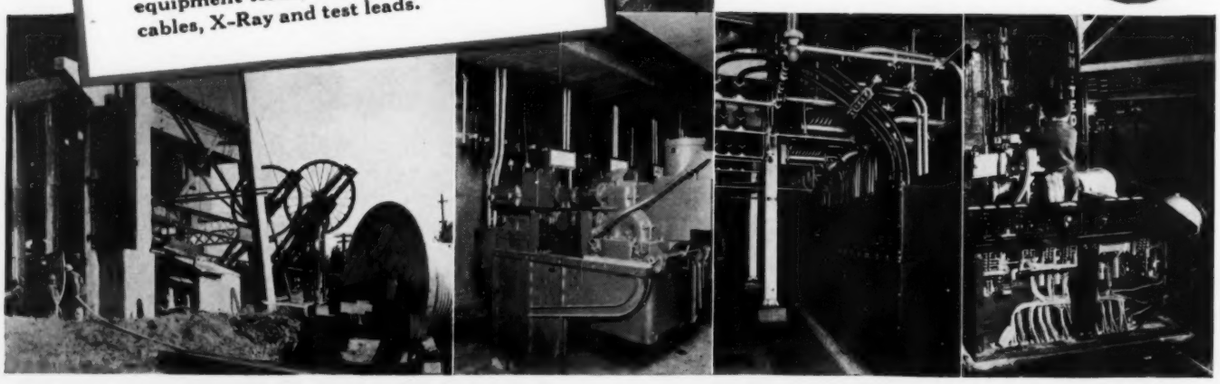
THE OKONITE COMPANY
PASSAIC, NEW JERSEY
Offices in principal cities

USE OKOLITE FOR THESE JOBS

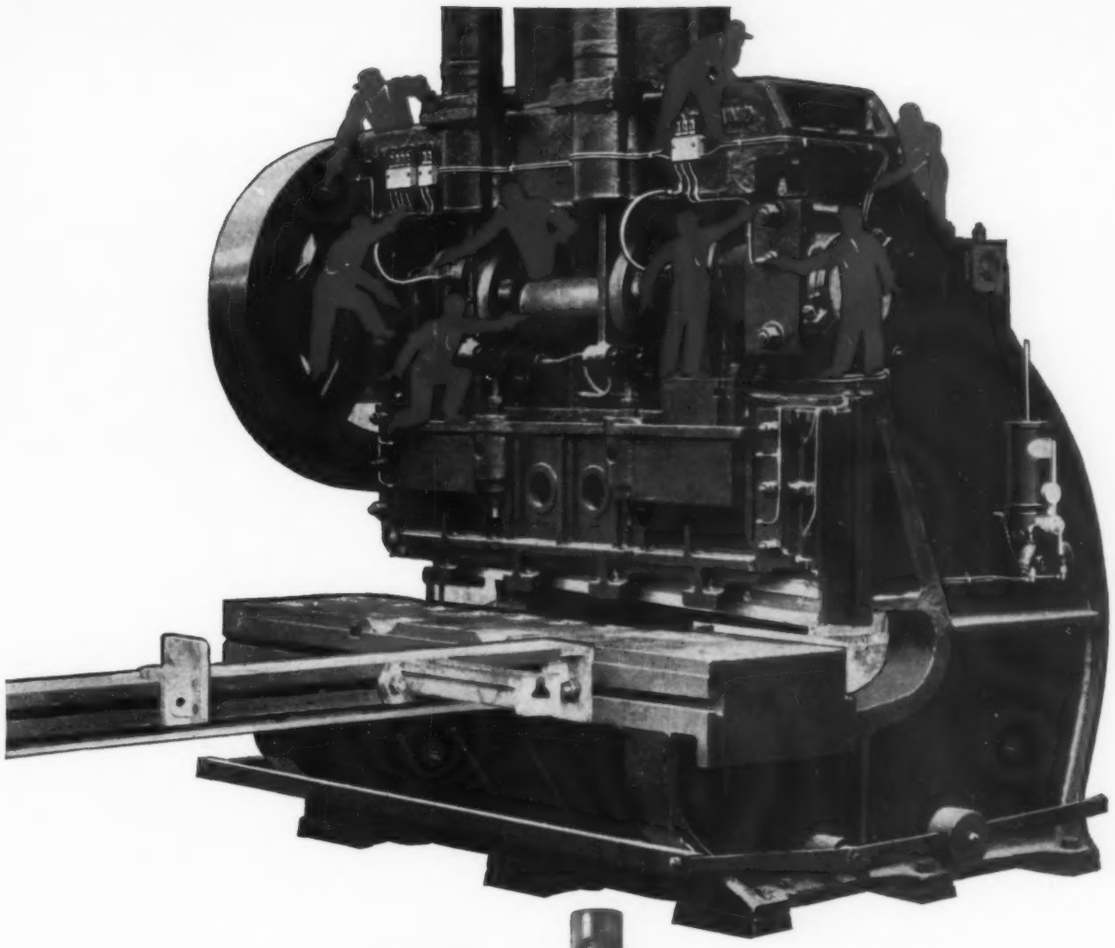
Interior, underground, aerial and submarine circuits—on portable cables, station and control wiring, apparatus and equipment leads, vertical risers and shaft cables, X-Ray and test leads.

Save Vital Materials and Labor

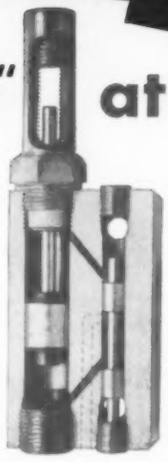
Okolite moisture-resisting insulation does not require a lead sheath. Splices and terminals are simplified. Use Okolite High Voltage Corona resisting tape.



OKONITE INSULATED WIRES AND CABLES



An Expert "Oiler" at every bearing



The Farval Dualine Measuring Valve is your expert oiler at each individual bearing on your machines.

1. He measures out the exact quantity of lubricant required by *each individual* bearing—no more, no less.
2. He shoots it into the bearing under hydraulic pressure from the Farval Central Station.
3. He hoists the telltale to show you the job is done.
4. He delivers *another* charge of clean, fresh lubricant at regular intervals. With Farval, never a bearing is missed!

The Farval Centralized System of Lubrication is simple and positive, consisting of a manual or automatic Central Pumping Unit, connected to the Dualine Measuring Valves located at bearings they serve.

Farval on your equipment will quickly pay for itself, then will *keep on earning* by: reducing power consumption as much as 30%—increasing life of bearings up to 10 times—lowering maintenance cost by 75%—prolonging life of equipment indefinitely.

The Farval Corporation, 3278 East 80th Street, Cleveland, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Manufacturers of Automotive and Industrial Worm Gearing.
In Canada: PEACOCK BROTHERS LIMITED

FARVAL

CENTRALIZED SYSTEMS OF LUBRICATION

Cut Shut-Down Time

with Heppenstall Shear Knives

You'll change knives less often if you use Heppenstall Shear Knives. They cut cleaner and stay in the shears longer between grinds, because they are made of the finest special analysis alloy steel in Heppenstall's own electric induction furnaces. Forging, annealing, machining, heat treating, and grinding are all done with meticulous care according to methods developed through more than fifty years of quality shear knife manufacture. • Let Heppenstall Service Engineers add their experience to yours and help you solve shearing problems. Call upon them without obligation. And next time you order, specify Heppenstall. Use knives that deliver more tons per grinding. Write for full information, Box E2, Heppenstall Co., 4620 Hatfield St., Pgh., Pa.

Heppenstall

PITTSBURGH DETROIT BRIDGEPORT

HEPPENSTALL H QUALITY

Forging Fine Steels for More Than Fifty Years

THIS BAKER TRUCK broke records in 1923!

Still going strong in 1942!!

February 14, 1923

ustrial Truck Division
ker-Raulang Company
, Ohio

Gentlemen:

The new Ram Car went into service yesterday. The first turn handled from the 14" mill was 412000#. She did the work very nicely and efficiently and has made such a difference in the appearance of the place already that the impression created in the minds of wise ones is beyond description. The way will be open for more rams shortly.

Here is something to talk about, a few days ago the 'original' ram loaded a car of 98000# in coils in just 42 minutes. This is a record to shoot at.

Yours very truly,

XXXXXXXXXXXXXXXXXXXX

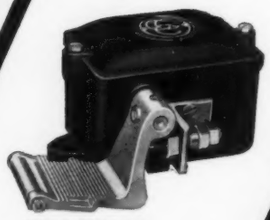
Nineteen years ago Baker solved a vital handling problem for the Steel Industry, when it introduced the ram truck. The second ram truck ever built was purchased by a large steel producer at Warren, Ohio. In going through some old files, we came across the letter at the right, showing how this truck was received. Immediate savings of 35 man hours per car loading were gained.

Since 1923 the identity of this mill has been lost in a merger. The Steel Industry has expanded to gigantic proportions. Ram trucks have been accepted as standard equipment for handling coils. Yet this pioneer Baker Ram Truck, having handled millions of tons of steel, is still on the job—still turning in its full quota of work, day in and day out.

Long life in an industrial truck depends on advance design as well as on sturdy construction. Baker Trucks are designed to delay obsolescence, and are made to take plenty of abuse without showing their age. Let us demonstrate how they can serve you in your plant.

BAKER INDUSTRIAL TRUCK DIVISION *of The Baker Raulang Company*
2166 WEST 25th STREET • • • • • CLEVELAND, OHIO

TYPE FSL 11, FSL 22, FSL 33
FOOT SWITCH WITH LATCH



TYPE FWS 22
WITH STOP FOOT SWITCH

TYPE FWLS 22 LATCHING
POSITIONED FOOT SWITCH

TYPE FRS 22 DOUBLE
PEDAL FOOT SWITCH

TYPE FS 44
4 POLE FOOT SWITCH

As part of the "3C" share toward "V for Victory", the above Bulletin 101 Heavy Duty Foot Operated Master Switches are offered for Mill and Industrial Service.

Furnished with or without latch, Right or Left Pedal, Dust Tight (NEMA IC 50-28), Water Tight (NEMA IC50-43) with Moving Finger Mechanism interchangeable on all Types, these switches are adaptable to a wide variety of applications.

In hundreds of plants engaged in production of Defense materiel, "3C" Foot Switches are providing dependable low-maintenance Service. A fully descriptive Bulletin 101 is yours for the asking.

CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

"Techni"

PROCESS WORK ROLLS

Give Better Surface Finish . . .

More Rolled Tons Per Grind

The Rolls with the Red Wabblers

Other Mackintosh-Hemphill Products:

Rolling Machinery

Shape Straighteners

Strip Coilers

Shears

Levellers

Pinions

Special Equipment

Iron-Steel Castings

The NEW Abramsen Straightener

Improved Johnston Patented Corrugated Cinder Pots and Supports

Heavy Duty Engine Lathes

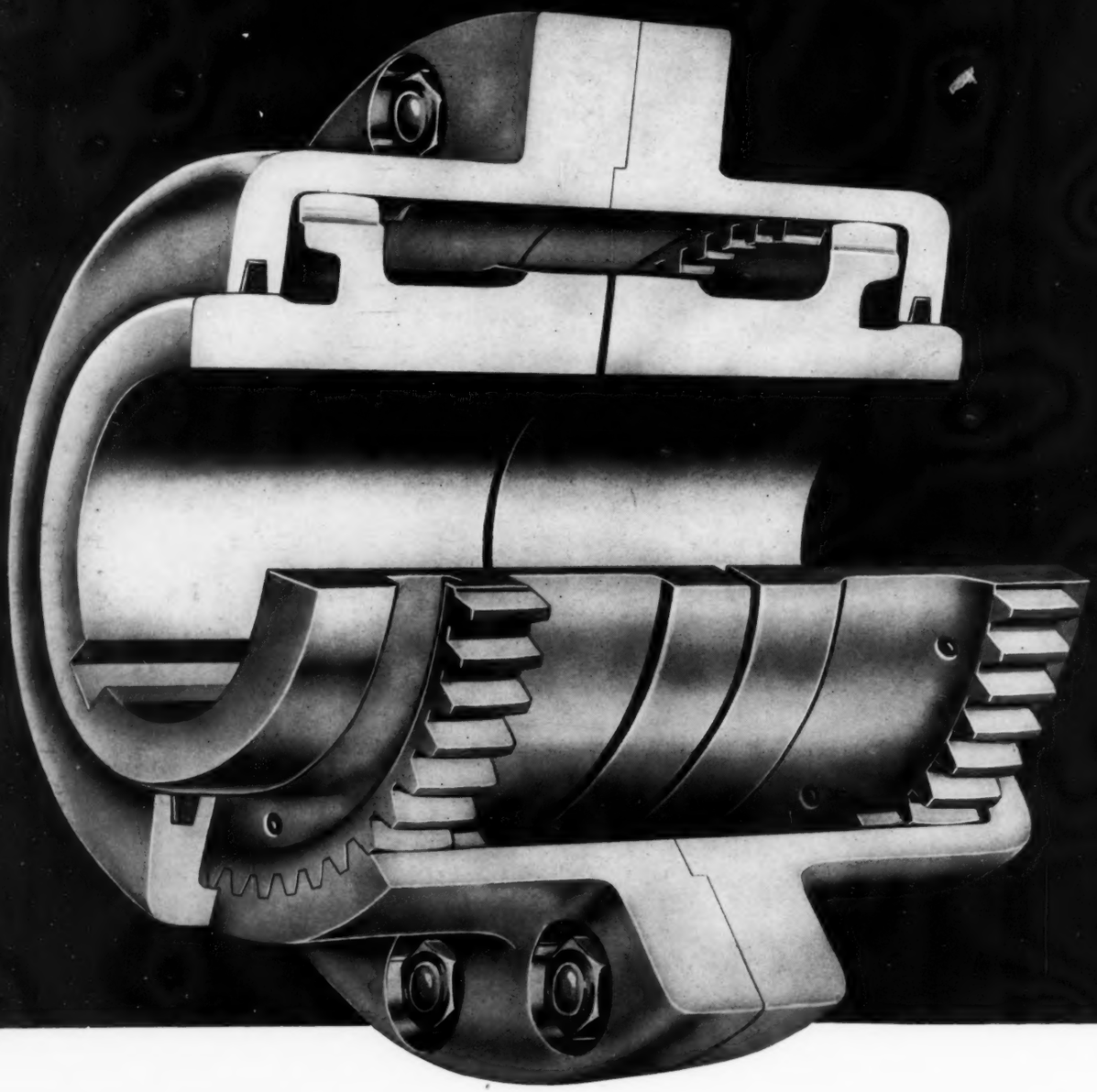
"Techni" Process Rolls have proved over a period of years that they give exceptional tonnage. And as applied to Strip Mill Rolls, they are tougher, have fine grain necks and bodies, denser chill, and ideal response to heat.

"Techni" Process was developed exclusively by Mackintosh-Hemphill. It regulates the quality and grain size of the rolls with as much exactness as the best modern steel practice regulates the quality of steel. Let Mackintosh-Hemphill help you get the most for every roll dollar you spend.

Since 1803—Pioneers, Engineers and Builders

MACKINTOSH-HEMPHILL COMPANY . . . Pittsburgh and Midland, Pennsylvania

POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

HELPING TO ATTAIN MAXIMUM PRODUCTION

at Algoma Steel...

LINK-BELT

CONVEYORS

CAR SPOTTERS · CHAIN DRIVES

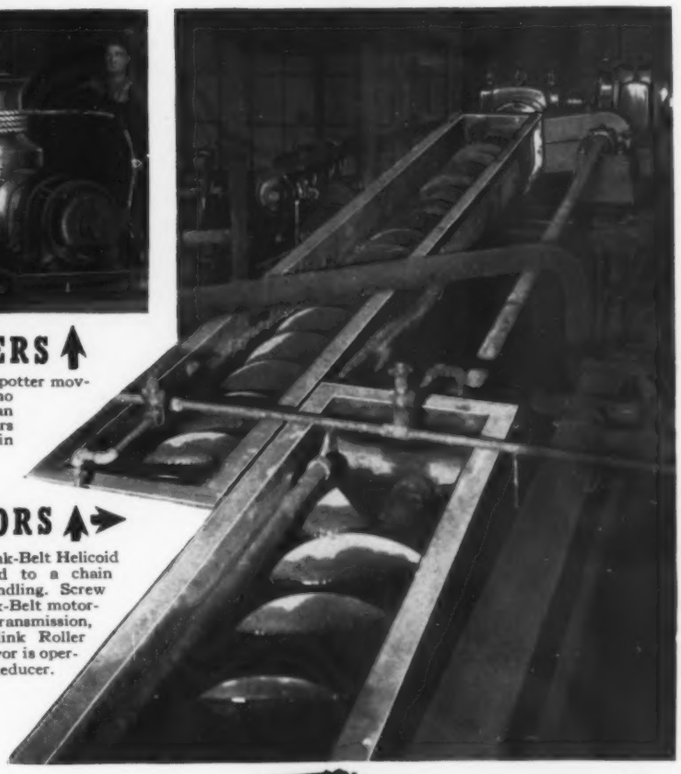
CHAIN CONVEYOR

Splice bars "on the move" on double-strand Link-Belt Steel Chain Conveyor.

CAR SPOTTERS

Link-Belt No. 10A Electric Car Spotter moving car of steel in Algoma plant—no waiting for switch engine. One man can place from one to six loaded cars exactly where wanted. Four units in service.

Algoma's new boilerhouse is equipped with Link-Belt coal handling machinery, consisting of a track hopper, apron feeder conveyor, bucket elevator, overhead distributing conveyor, and 750-ton Berquist overhead bin complete with discharge gates and chutes to pulverizers.



SCREW CONVEYORS

Steel balls are quenched in these Link-Belt Helicoid (screw) conveyors and discharged to a chain transfer conveyor for further handling. Screw conveyors are operated from a Link-Belt motorized P.I.V. Gear Variable Speed Transmission, Worm Gear Reducer and Silverlink Roller Chain Drive. Chain transfer conveyor is operated from a Link-Belt Motorized Reducer.

These are just a few of the items of Link-Belt conveying and power transmitting equipment that are helping Algoma Steel Corporation, Ltd., Sault Ste. Marie, Ont., attain maximum production in Our War Effort. Delays and inefficiency must be eliminated everywhere. Link-Belt engineers are at your service. Catalogs on request.

LINK-BELT COMPANY

Engineers and Manufacturers of Specialized Machinery for the Iron and Steel Industry 3731

Chicago Indianapolis Philadelphia Atlanta Dallas Pittsburgh Cleveland Detroit San Francisco

IN CANADA: Link-Belt Limited, Toronto, Montreal, Vancouver, Swastika

Offices, warehouses and distributors in principal cities

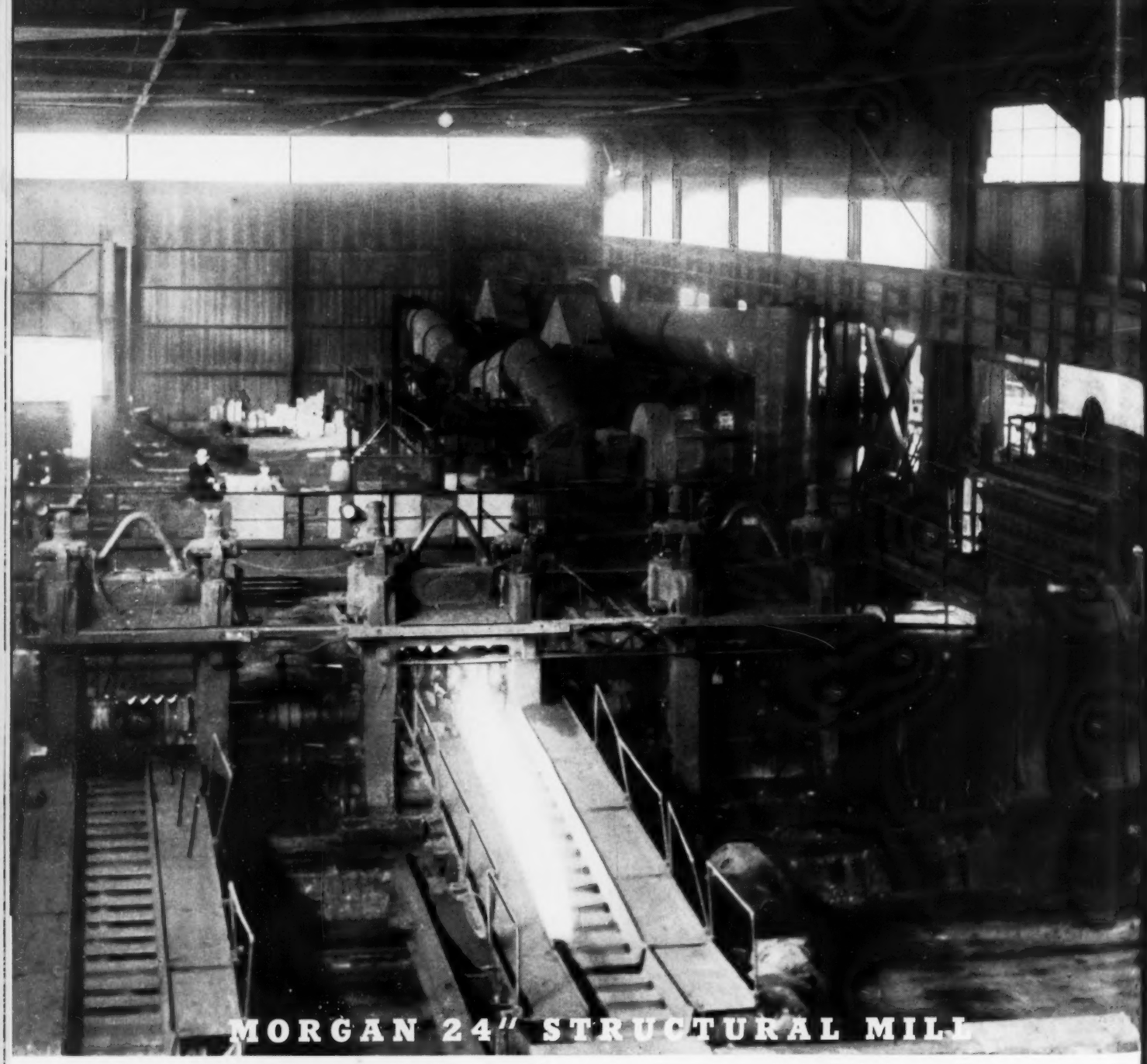
APRON CONVEYOR

Splice bars are conveyed through oil tempering tank on a Link-Belt Apron Conveyor. Two such conveyors, each 54" wide, are in use.

LINK-BELT

EQUIPMENT INCLUDES: Complete line of Chains for transfer tables, coil conveyors, furnace conveyors, feeder and catcher tables, sheet pilers, draw bench and other equipment. . . Elevators and Conveyors of all types . . . Vibrating Screens . . . Dryers and Coolers . . . Skip Hoists . . . Car Spotters and Haulage Systems . . . Portable Conveyors and Bucket Loaders . . . Silent and Roller Chain Drives . . . Speed Reducers . . . Variable Speed Transmissions . . . Sprockets . . . Elevator Buckets . . . Gears . . . Clutches . . . Couplings . . . Friction Fighter Self-aligning Ball and Roller Bearings . . . Babbitted Bearing Units . . . Base Plates . . . Take-Ups, etc.

BUILT BY MORGAN *Engineering*



MORGAN 24" STRUCTURAL MILL

● Among the many types of mill equipment built by Morgan is the above 24" structural mill, consisting of three three-high stands served on each side by two traveling tilting tables and tail tables with transfers.

A two-high finishing mill located about 170'-0" beyond was also furnished. In addition, all necessary auxiliary equipment to handle billets and rolled shapes to the finished product was furnished with this installation.

★ **DESIGNERS • MANUFACTURERS • CONTRACTORS**

★ BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS
ELECTRIC TRAVELING CRANES • CHARGING MACHINES
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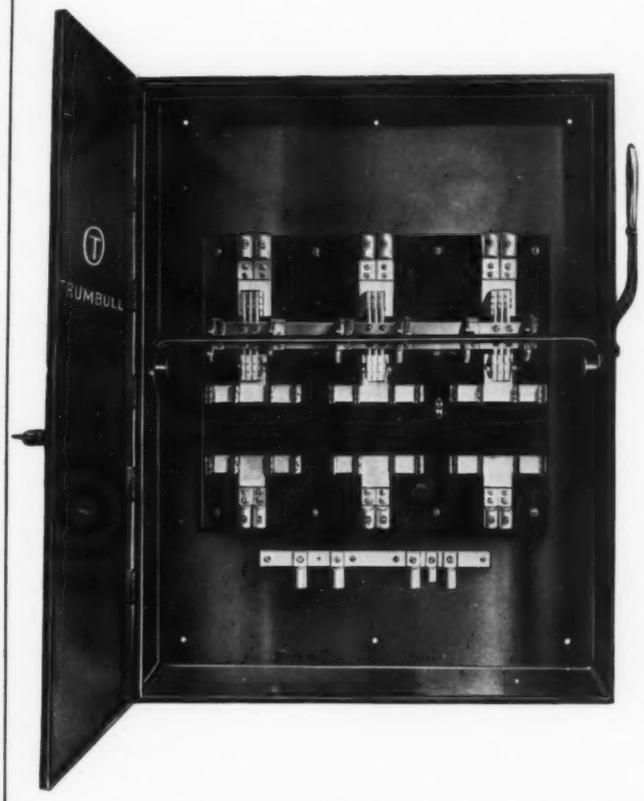
★ ELECTRIC WELDED FABRICATION • LADLE CRANES
STEAM HAMMERS • STEAM HYDRAULIC FORGING

★ PRESSES • SPECIAL MACHINERY FOR STEEL MILLS

THE MORGAN ENGINEERING CO., Alliance, Ohio

★ Pittsburgh, 1420 Oliver Building

STEEL MAN'S SAFETY SWITCH



TRUMBULL "TYPE A"

Performance of Trumbull Type "A" Heavy Duty Safety Switches in thousands of steel mill installations has demonstrated, over the years, that this is truly the steel man's switch.

Every feature of this Type "A" has been built for battle. It can take a terrible beating and still stand up . . . even under the continuous 24-hour grind of defense-time steel mill service.

Extremely strong mechanically, carefully designed and adjusted electrically and constructed throughout for positive safety, the Trumbull Type "A" answers every demand for efficient control of heavy duty light and power installations.

Write for Trumbullaid Circular No. 302.

WHY STEEL MILLS PREFER THEM

- Parts FRONT MOUNTED, allowing examination under load by authorized person . . . releasable interlock.
- Insulating fibre cross-bar prevents arcing due to accumulation of dust on yoke.
- Quick-make, quick-break feature prevents pitting of contacts, lengthens service life. Interlocking cover. Rated in horse-power for motor disconnect.
- Silver plated contacts . . . solderless lugs . . . reinforced fuse holders . . . arc quenchers.

THE TRUMBULL ELECTRIC MANUFACTURING COMPANY
PLAINVILLE, CONN.

THE TRUMBULL ELEC. MFG. CO. — PLAINVILLE CONN. U.S.A.

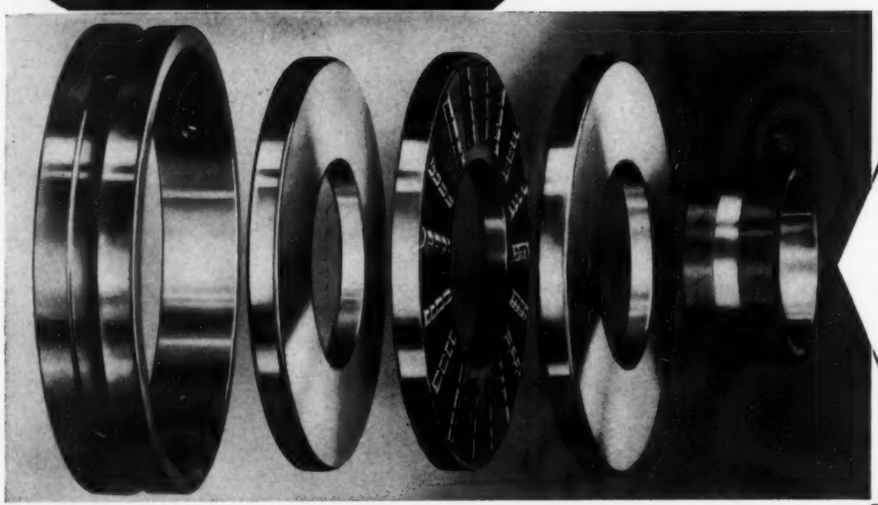
OTHER FACTORIES AT NORWOOD (CINN.) O. — SEATTLE — SAN FRANCISCO — LOS ANGELES — TRENTON, N. J. (PORCELAIN)

Approach the Wear and Maintenance Problems of the 168-HOUR WEEK from the *RIGHT-ANGLE ★

Use
ROLLWAY'S
RIGHT-ANGLED BEARING LOADINGS
for longer life . . . heavier loads . . . and higher speeds . . . .

When three shifts work where one worked before . . . or three pieces are machined in the time usually required for one . . . ROLLWAY'S SOLID CYLINDRICAL ROLLER BEARINGS solve the complicated wear and maintenance problems. For Rollway Roller Bearings reduce every load to its simplest components, *pure radial and pure thrust.* They carry each of these two components on a separate bearing assembly—AT *RIGHT ANGLES* TO THE ROLLER.

That means solid cylindrical rollers of greater total mass and cross-section area in a given space. It means smaller unit-load per roller . . . longer wear . . . increased load capacity . . . and reduced maintenance attention. It assures true rolling . . . no pinching or wedging . . . less sliding friction . . . and lower torque. It permits change-over from other kinds of bearings to Rollways of *higher load capacities* without increasing boundary dimensions.



TYPE SDT Thrust Bearing—double-acting.

★
All Thrust Loads carried at Right Angles to the Roller Surface.
All Radial Loads Carried at Right Angles to the Roller Surface.

Easy starting that does not depend upon a constantly maintained oil film . . . short, accurately dimensioned rollers that are staggered to equalize distribution of wear . . . and thrust plates that are held to extremely close limits for parallelism . . . ALL give Rollway Thrust Bearings maximum load capacity coupled with freedom from Brinell effect, plus a relatively true rolling action undamped by excessive rubbing contact.

ASK *for an "Engineered to the Job" recommendation. Design is basic in bearing applications. Problems are complex. Our specialized engineering service is at your service—without cost. Just send us your plans.*

Type MN
Double Width
Radial Bearing

ROLLWAY BEARING COMPANY, INC., SYRACUSE, N. Y.

BUILDING HEAVY-DUTY BEARINGS SINCE 1908 **BEARINGS**

OXY-ACETYLENE FLAME-GOUGING
is a Useful Shop "Tool"

What it is:

Flame-gouging is a variation of oxy-acetylene cutting. This process removes a fully-controlled groove or "gouge" of surface metal—without harm to adjacent areas. All that you need to use for gouging is a *standard* Oxweld C-31 or C-32 cutting blowpipe, and a gouging nozzle. These nozzles are available in three different sizes to fill all requirements.

How it is used:

The most common uses of flame-gouging include:

- —Removal of faulty or temporary welds.
- —Gouging the backside of electric welds.
- —Preparing plate edges for welding.
- —Maintenance, reclamation, and scrapping.
- —Redesign of forgings and castings.
- —Preparing broken castings for repair.
- —Fabrication of parts requiring a "groove."

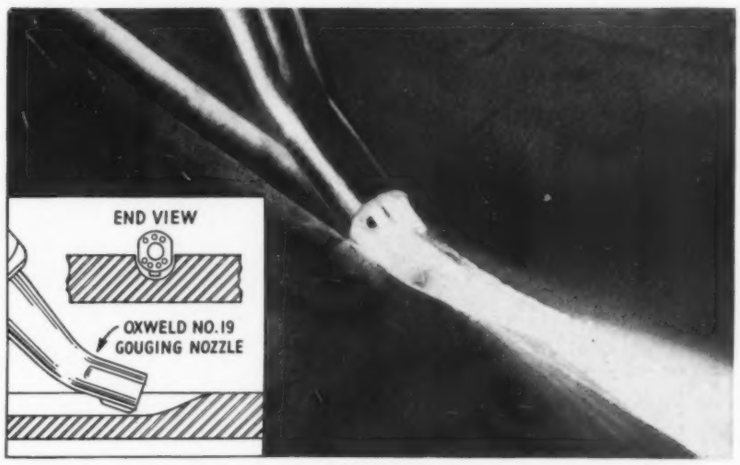
The uses of this process seem to be limited only by the ingenuity of the operator and the shop needs that arise.

What its advantages are:

In addition to use in large fabricating plants, gouging offers particular advantages for the small shop—because it can do so many things that formerly required equipment not found in small shops. Some advantages of gouging are:

- —It reduces shop noise.
- —It is easy to learn and use.
- —It requires only a small investment.
- —It replaces expensive tools and machining operations.
- —It eliminates costly hours of grinding and chipping.

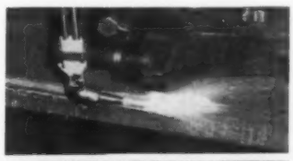
Write for descriptive literature—If you want to know more about this process, write for "Flame-Gouging, An Economical Method of Grooving Steel." A copy will be sent without obligation.



The illustration and sketch show an Oxweld No. 19 gouging nozzle making a groove ⅜ in. wide and ¼ in. deep in steel plate.

A Few Typical Uses

In the construction of pressure vessels and tanks, machine-cut plate edges (1) are welded as in (2), then gouged as in (3), for the back-up weld (4).



In preparing steel for welded fabrication, mechanized gouging with Oxweld machines is often used.

One user reported that he makes liquid-level gauges by gouging a channel in steel plate, then facing it with glass.

Studs temporarily welded on to steel pipe, to hold a testing head, are easily gouged off with Oxweld equipment.

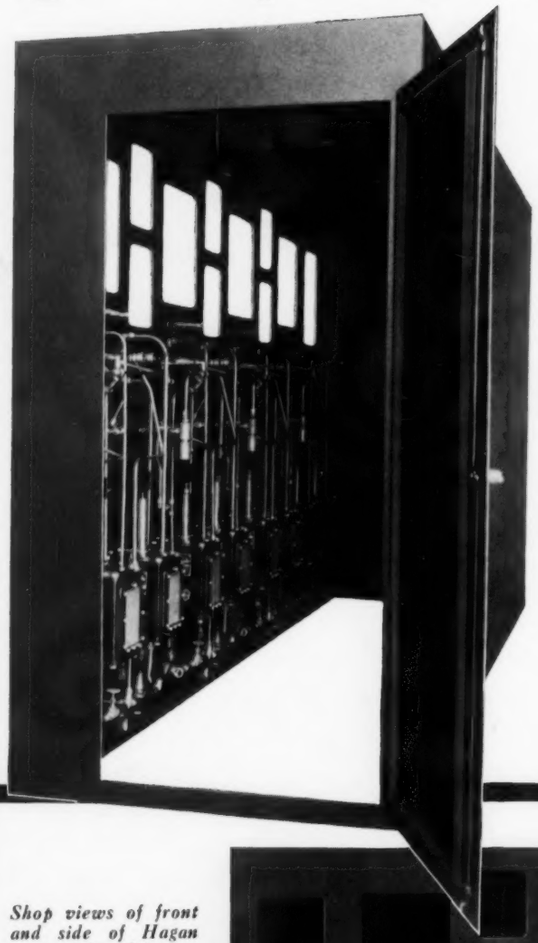
THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
General Office: New York UCC Offices in Principal Cities
In Canada: Dominion Oxygen Company, Limited, Toronto

LINDE OXYGEN . . . PREST-O-LITE ACETYLENE . . . UNION CARBIDE
OXWELD, PUROX, PREST-O-WELD APPARATUS . . . OXWELD SUPPLIES

The words "Linde," "Prest-O-Lite," "Union," "Oxweld," "Purox," and "Prest-O-Weld" are trade-marks of Units of Union Carbide and Carbon Corporation.

Ingot capacity increases 5-10%

in soaking pits rebuilt with Hagan Automatic Control

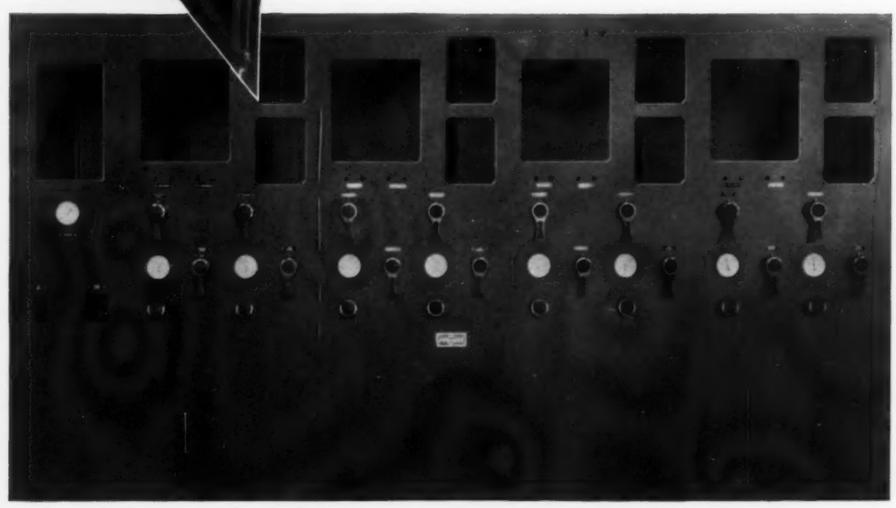


IF circumstances are such that new soaking pits cannot be installed, substantial increases in capacity can still be obtained by applying Hagan Automatic Combustion Control to older-style pits.

Soaking pits are often the bottlenecks that choke production. A capacity increase of 5% or 10% here may mean a similar increase all along the line. By maintaining correct fuel-air ratio and furnace pressure, Hagan Control helps make such increases possible.

Fully automatic Hagan Control assures more uniform heating, faster rolling and fewer rejects. Unproductive bottom-making is reduced from once a day to once every week or two, thus keeping pits in *steady* production for *longer* periods.

Hagan Control pays for itself in a few months by reducing fuel and labor costs. It is one of the few ways left to counteract rising prices. Get complete details.



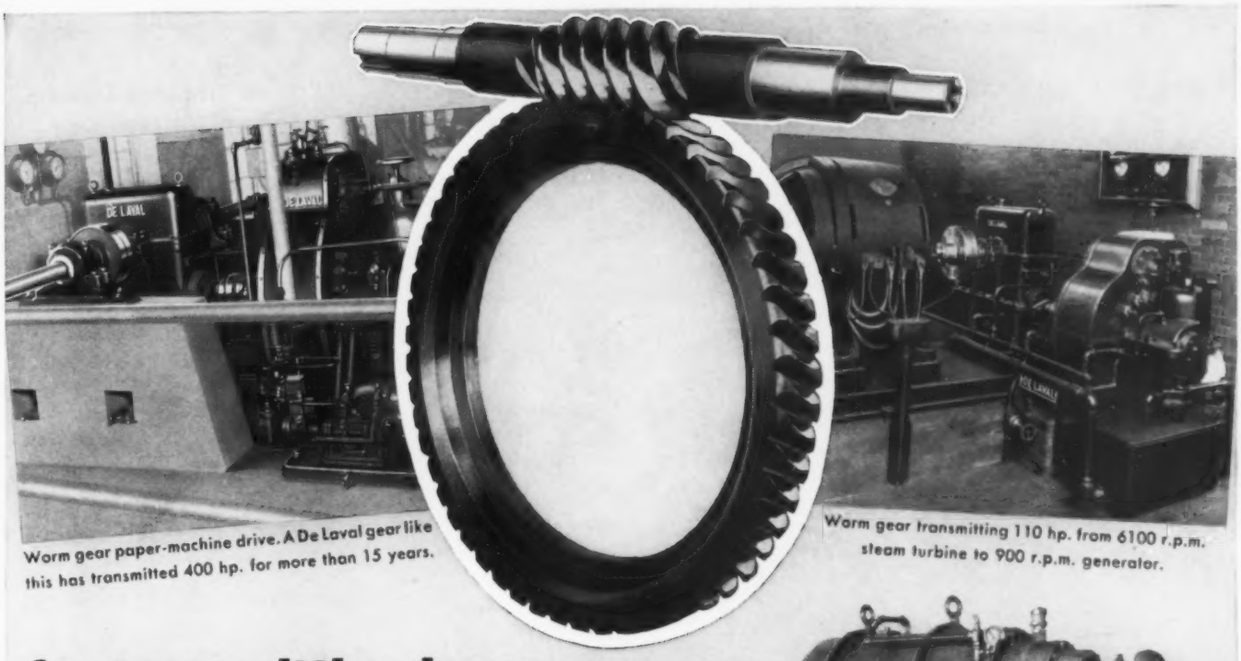
Shop views of front and side of Hagan Control Panel for rebuilt soaking-pit installation in an Ohio steel mill. Cut-outs are for instruments to be mounted in plant.

•

HAGAN CORPORATION · 300 ROSS STREET · PITTSBURGH, PA.

HAGAN *Automatic* COMBUSTION CONTROL

The pioneer . . . and still the leader



Worm gear paper-machine drive. A De Laval gear like this has transmitted 400 hp. for more than 15 years.

Worm gear transmitting 110 hp. from 6100 r.p.m. steam turbine to 900 r.p.m. generator.

for transmitting large powers

continuously

select DE LAVAL WORM GEARS

13¼ to 1 ratio worm gear for transmitting 300 hp. from a 1750 r.p.m. motor to drive a dredge cutter head.

The case hardened steel worms, bearing-bronze wheels, and copious lubrication give long life, without requiring attention other than occasional checking of oil level. The efficiency is high, reaching 97 per cent for certain ratios, and does not recede, but rather improves, with use. The transmission of power is shockless and noiseless.

Our engineers gladly supply data and give competent advice for the solution of speed transformer problems. Ask for Leaflet W-1128.

One of eight steam turbine-worm gear drives of induced draft fans; 185 hp. each from 3760 r.p.m. turbine speed to 550 r.p.m. fan speed.

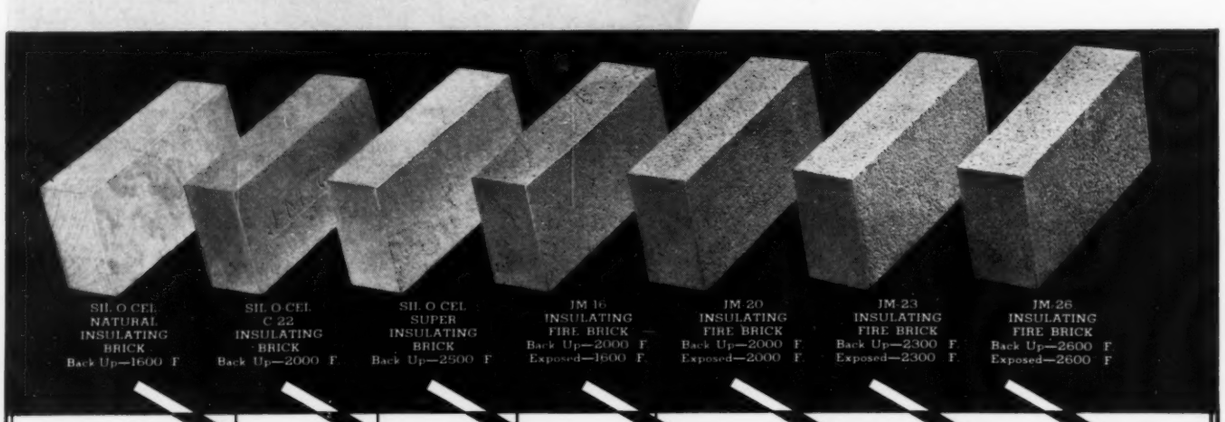
DE LAVAL WORM GEAR DIVISION

of the De Laval Steam Turbine Co., Trenton, N. J.

MANUFACTURERS OF TURBINES STEAM, HYDRAULIC, PUMPS CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT, MOTOR-MOUNTED, MIXED-FLOW, CLOGLESS, SELF-PRIMING CENTRIFUGAL BLOWERS and COMPRESSORS, GEARS WORM, HELICAL and FLEXIBLE COUPLINGS

THE *RIGHT* BRICK for EVERY TEMPERATURE ...for EVERY SERVICE

Listed below are details on the properties of the new complete line of J-M Insulating Brick and Insulating Fire Brick. Each is designed for a specific temperature and service . . . can be relied upon for continued efficiency and economy. For further details, write Johns-Manville, 22 East 40th Street, New York, N. Y.


SIL-O-CEL NATURAL INSULATING BRICK Back Up—1600° F
SIL-O-CEL C-22 INSULATING BRICK Back Up—2000° F
SIL-O-CEL SUPER INSULATING BRICK Back Up—2500° F
JM 16 INSULATING FIRE BRICK Back Up—2000° F Exposed—1600° F
JM 20 INSULATING FIRE BRICK Back Up—2000° F Exposed—2000° F
JM 23 INSULATING FIRE BRICK Back Up—2300° F Exposed—2300° F
JM 26 INSULATING FIRE BRICK Back Up—2600° F Exposed—2600° F

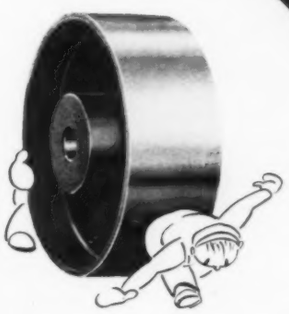
Properties							
Density—lb. per cu. ft.	30	38	40	22	31	38	44
Transverse Strength—lb. per sq. in.	140	115	90	70	100	135	150
Cold Crushing Strength—lb. per sq. in.	400	700	300	70	125	170	165
Linear Shrinkage—%	1.4 @ 1600° F	0.8 @ 2000° F	2.0 @ 2500° F	0.0 @ 2000° F	0.0 @ 2000° F	0.0 @ 2300° F	0.5 @ 2600° F
Reversible Thermal Expansion—Percent	0.1 @ 1600° F	0.7 @ 2000° F	1.29 @ 2000° F	0.5—0.6 @ 2000° F	0.5—0.6 @ 2000° F	0.5—0.6 @ 2000° F	0.5—0.6 @ 2000° F
Conductivity at Mean Temperature	∥ ⊥						
500° F	1.01 .67	1.67	1.70	.75	1.01	1.26	1.61
1000° F	1.13 .79	1.88	1.95	1.01	1.19	1.49	1.90
1500° F	1.24 .90	2.08	2.19	1.41	1.49	2.05	2.61
2000° F	... ..	...	2.45	...	1.91	3.37	4.29
Recommended Service							
Back Up	1600° F	2000° F	2500° F	2000° F	2000° F	2300° F	2600° F
Exposed	....	....	....	1600° F	2000° F	2300° F	2600° F
Recommended Mortar for Setting Brick	Sil-O-Cel Mortar	Sil-O-Cel Mortar	Sil-O-Cel Super Brick Mortar	J-M No. 1626 Cement	J-M No. 1626 Cement	J-M No. 1626 Cement	J-M No. 1626 Cement

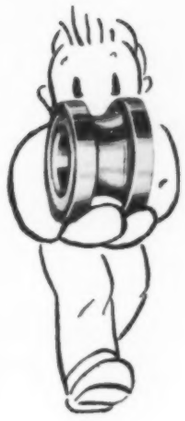
Note:—1. Above tests are in accordance with ASTM tentative standards.
2. Conductivity is expressed in Btu. in. per hr. per sq. ft. deg. F. at the designated mean temperatures.
3. ∥—with heat flow parallel to brick strata.
⊥—with heat flow perpendicular to brick strata.

Johns-Manville
INDUSTRIAL INSULATIONS

35 YEARS OLD—

Thank You!





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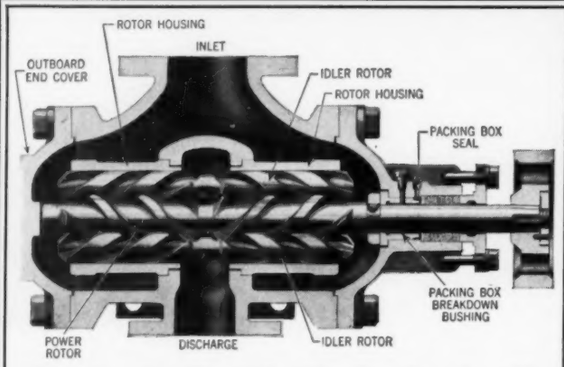
THE TOOL STEEL GEAR & PINION COMPANY

CINCINNATI, OHIO



ESSENTIALS

The De Laval-IMO Oil Pump

1—*runs* at motor or turbine speeds,
2—*delivers* any oil in any volume against any pressure,
3—*occupies* small space, and
4—*uses* power efficiently.

But DOES NOT

a — have valves, gears, separate bearings or oscillating parts,
b — set up pulsation or vibration,
c — have high-pressure packing boxes, or
d — require disconnection of piping or disturbance of motor for internal inspection.

Ask for Catalog I-84.

IMO
I MOVE OIL

IMO PUMP DIVISION
of the De Laval Steam Turbine Company
Trenton, New Jersey

Avoid machine shut-downs caused by bearing failures . . . Prevent delays in producing war orders . . . .

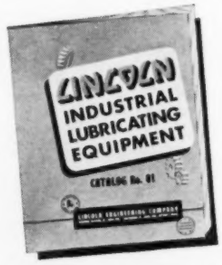
★ **use** ★

LINCOLN LUBRICATING EQUIPMENT

for all machines requiring periodic lubrication

As pioneer builders of lubricating equipment, and as one of the largest manufacturers in the field, Lincoln is well qualified to supply the correct lubricating equipment for your needs.

This great line includes many types of hand, electric and air operated grease guns, automatic and manually controlled centralized systems, and a full range of all types and sizes of grease fittings.



142-3

Send for Catalog No. 61

LINCOLN ENGINEERING COMPANY
PIONEER BUILDERS OF LUBRICATING EQUIPMENT
ST. LOUIS, MO.

DEFENSE AGAINST *Short Circuits...*

Oil leaks or is thrown from bearings and gets on armatures. Resulting short-circuits cause expense and delays that hold back production.

Drip-less, waste-less NON-FLUID OIL stays where applied, even under extreme heat and vibration. It keeps off windings —"burn-outs" are avoided. What's more, you save on oil and application cost. For NON-FLUID OIL outlasts oil many times over.

Used successfully in leading iron and steel mills. Send for testing sample today—prepaid —NO CHARGE.

•

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IN U.S. PAT OFFICE & FOREIGN COUNTRIES

MODERN STEEL MILL LUBRICANT

Better Lubrication at Less Cost per Month

P&H
OVERHEAD CRANES

DELIVERY DATES WITHIN ± 3%

Because faithful delivery promises are so important during these days of carefully scheduled defense production, P&H has been keeping its delivery dates within remarkably close limits.

When you desire an overhead crane installation in the shortest possible time, we urge that you consider the selection of a P&H crane of conventional design, choosing one which has ample factors of safety to meet your specific service requirements. When P&H has full control of crane production, including all such items as electrical apparatus, you benefit not only through prompter deliveries but also through greater dollar value per dollar of cost.

P&H is America's oldest and only crane builder producing complete electrical equipment.

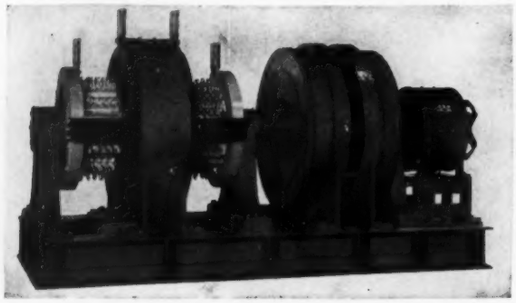
Gen. Office: 4455 W. National Ave., Milwaukee, Wis.

HARNISCHFEGER CORPORATION

ELECTRIC CRANES · EXCAVATORS · ARC WELDERS · P&H · HOISTS · WELDING ELECTRODES · MOTORS

Increase Production — Improve Quality

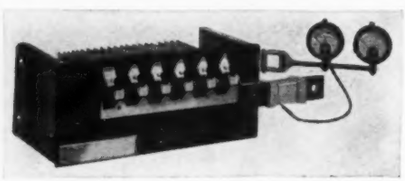
WITH THESE QUALITY-MADE COLUMBIA PRODUCTS



In these days of speed, speed, speed, you'll want to know the facts about Columbia Low Voltage Generators, Plating Tank Rheostats and Reversing Switches. For more than 15 years these Columbia products have been meeting the production and quality demands of the plating industry and, of relatively equal importance, we have them available now for prompt shipment.

Write us your needs and we will send you complete information immediately.

Columbia Low Voltage Generators are built in sizes of 100 to 20,000 amperes, 6 to 60 volts. They are available for electroplating service in sizes of 6 to 20 volts, 500 to 20,000 amperes; for anodic treatment of aluminum in sizes of 30, 40, 50 and 60 volts, 500 to 5,000 amperes.
Columbia Reversing Switches are of the double pole, double throw type for use as reversing switches or series parallel switches on circuits up to 15 volts, 200 to 2,000 amperes.
Columbia Rheostat sizes range from 15 to 5,000 amperes and with a 3 to 6 volt drop.



COLUMBIA ELECTRIC MFG. CO., 4512 Hamil ton Ave., Cleveland, Ohio

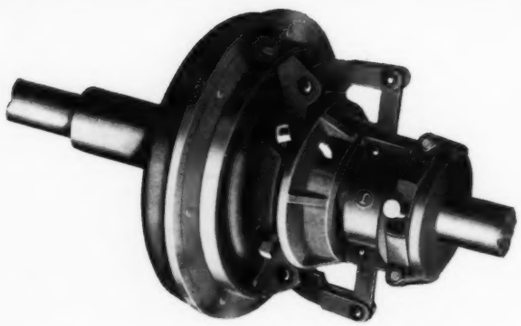
LOW VOLTAGE GENERATORS

COLUMBIA

PLATING TANK RHEOSTATS

REVERSING SWITCHES

JONES-LEMLEY FRICTION CLUTCHES



JONES-LEMLEY friction clutches are built for a broad range of shaft sizes and ratings in both enclosed and open types for sleeve and coupling work. In addition they are available in a line of Jones-Lemley friction clutch pulleys. This clutch modification is also used for gears, V-belt sheaves, sprocket wheels, etc. Sizes, ratings, dimensions, prices and other data are contained in Bulletin No. 60. Your request will bring a copy.

W. A. JONES FOUNDRY & MACHINE CO., 4431 Roosevelt Rd., Chicago, Illinois

Jones

HERRINGBONE — WORM — SPUR — GEAR SPEED REDUCERS • PULLEYS
CUT AND MOLDED TOOTH GEARS • V-BELT SHEAVES • ANTI-FRICTION
PILLOW BLOCKS • FRICTION CLUTCHES • TRANSMISSION APPLIANCES

OHIO ARMORED WEATHER PROOF CONNECTORS

Save time to make or break connections.

They are operated by hand, (See the Bayonet Joint in Cut.)

No Tools or Tape required.

No danger, live parts covered by insulated Iron Shell.

Two Pole Connectors have Automatic Spring Cover closing live end when not connected.

They also have support Ears for mounting (see cut).

Single Pole Connectors are furnished without Spring Closing Covers or Support Ears.

Cable Ends are No. 4 B & S Extra Flexible Insulated Wire.

Capacity 150 amperes continuous.

	Weight	Net Price
Single Pole Connectors . .	5 Lbs.	$12.00 Each
Double Pole Connectors . .	13½ Lbs.	$25.00 Each
Lower or Plug End Separately . . .		$ 7.50 Each

F. O. B. CLEVELAND

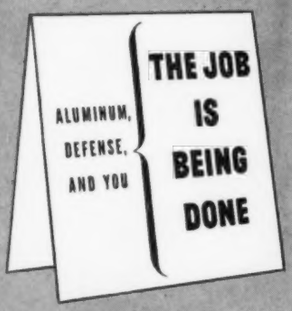
OHIO reliable MAGNETS

The OHIO Electric Mfg. Co.

5907 Maurice Avenue
Cleveland, Ohio

Today American Industry must have efficient and dependable operating equipment. Over a quarter of a century's experience in the manufacture of Oil Immersed Motor Control equipment is your assurance of dependability in Rowan products.
ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

THERE IS NO PRIORITY ON IMAGINEERING



EVERY INDUSTRY, every responsible man in industry, has the present duty of answering two questions.

FIRST ONE IS: Are we, am I personally, doing everything within my power for the war? Our answer here at Alcoa is a plain, unqualified, yes.

NEXT QUESTION IS: What are we doing about the day when we will all need business, which is the polite way of saying, when millions of jobs will be needed for the boys who come back, and for the boys who stayed back to make the weapons.

IMAGINEERING, you know, is the word we have coined to define what we business people have all got to do about the future; about the products we are going to make and the services we are going to be able to offer when this war is over. Imagineering is imagination plus engineering.

HOW DO YOU DO IT? One way would be to figure out, now, how to take advantage of all the aluminum that is going to be available.

QUICKEST WAY TO GET AT IT is to take one of your products or a piece of equipment that "just couldn't" be made of aluminum, and ask yourself, Why not?

MEANING, OF COURSE, why not light; why not stronger for the same weight; why not resistant to corrosion, and so on, ad infinitum. The first man in any line of business who calls tradition a liar, and things-as-they-are a millstone, is the man who is going places; the man who is going to make peacetime pay rolls.

THAT'S IMAGINEERING AT WORK. We've got some ideas here at Alcoa. We're trying to pass them out. We are looking for men who have made themselves receptive by doing some solid Imagineering on their own hook, in their own fields.

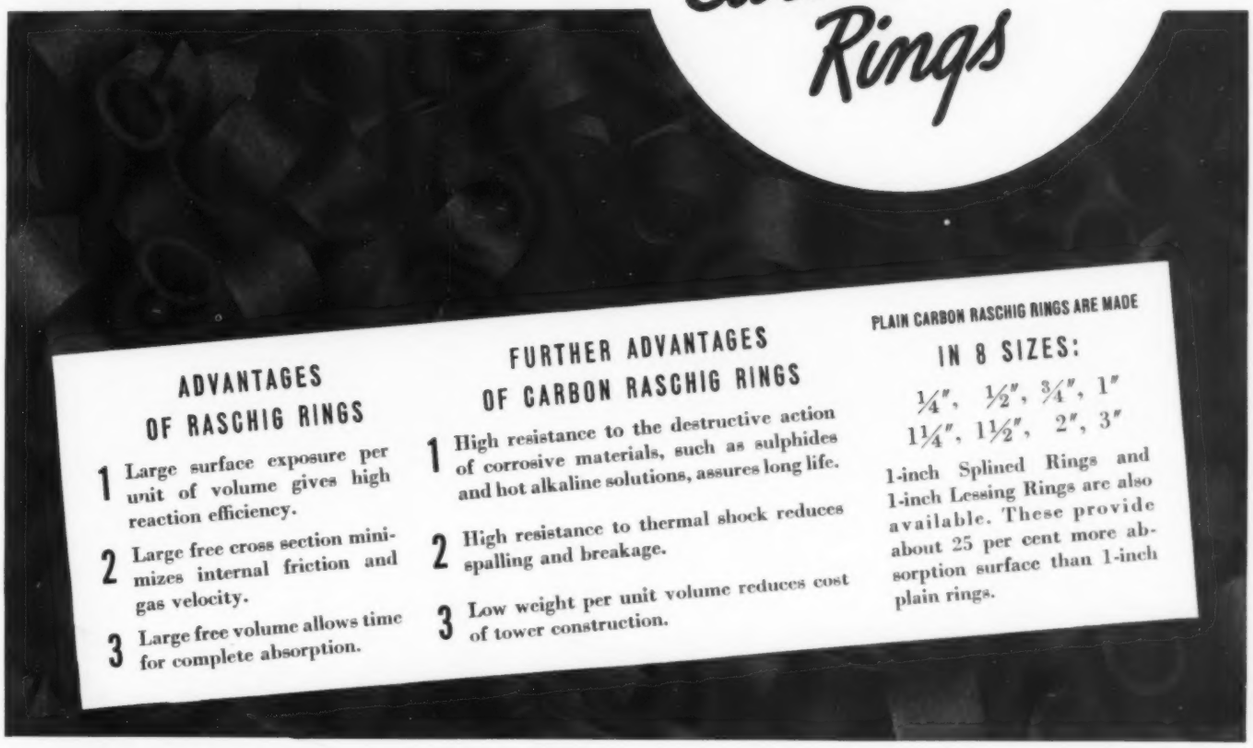
Aluminum Company of America, 2128 Gulf Building, Pittsburgh, Pennsylvania.

ALCOA ALUMINUM

FOR ALL PACKED TOWER PROCESSES

. . SUCH AS DEHYDRATION OF AIR AND THE RECOVERY OF HYDROGEN SULPHIDE

Use NATIONAL TRADE-MARK *CarbonRaschig Rings*



ADVANTAGES OF RASCHIG RINGS

1. Large surface exposure per unit of volume gives high reaction efficiency.
2. Large free cross section minimizes internal friction and gas velocity.
3. Large free volume allows time for complete absorption.

FURTHER ADVANTAGES OF CARBON RASCHIG RINGS

1. High resistance to the destructive action of corrosive materials, such as sulphides and hot alkaline solutions, assures long life.
2. High resistance to thermal shock reduces spalling and breakage.
3. Low weight per unit volume reduces cost of tower construction.

PLAIN CARBON RASCHIG RINGS ARE MADE IN 8 SIZES:

¼″, ½″, ¾″, 1″
1¼″, 1½″, 2″, 3″

1-inch Splined Rings and 1-inch Lessing Rings are also available. These provide about 25 per cent more absorption surface than 1-inch plain rings.

OTHER CARBON, GRAPHITE AND "KARBATE" PRODUCTS USED IN THE IRON AND STEEL INDUSTRY

★ Mold plugs, cores, inserts, small molds and crucibles.

★ Brick and slabs for lining troughs and acid processing equipment.

★ Rolls and bearings for continuous strip pickling tanks.

★ Pipe, valves and fittings for heating pickling solutions and for other uses in contact with corrosive materials.

"Karbate" products are carbon or graphite materials made impervious to seepage of liquids or gases under pressure.

LET US SHOW YOU HOW THEY CAN SAVE MONEY FOR YOU

"NATIONAL" CARBON, GRAPHITE AND "KARBATE" PRODUCTS ARE EFFECTING SUBSTANTIAL ECONOMIES IN STEEL PLANT OPERATION AND MAINTENANCE

NATIONAL CARBON COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
UCC
Carbon Sales Division, Cleveland, Ohio
General Offices: 30 E. 42nd St., New York, N. Y.
Branch Sales Offices: NEW YORK - PITTSBURGH - CHICAGO - ST. LOUIS - SAN FRANCISCO

The words "National" and "Karbate" are trade-marks of National Carbon Company, Inc.

TIME *Marches On*

In 1921, NORMA-HOFFMANN introduced the Cup Mounting—the forerunner of all self-protected ball bearings. From this, through progressive stages (as shown above) has evolved the NORMA-HOFFMANN "CARTRIDGE" BALL BEARING—an ultra-modern type embodying 30 years of PRECISION BEARING manufacture and offering to industry the following distinctive advantages:

SIMPLER AND MORE ECONOMICAL MACHINE DESIGN, due to elimination of many costly mounting parts and machining operations, otherwise required; EASIER AND FASTER MACHINE ASSEMBLY AND DISASSEMBLY, since the "CARTRIDGE" BEARING is an integrally sealed unit needing no complementary mounting parts; 100% GREATER GREASE CAPACITY, due to double-row width creating a greatly enlarged grease reservoir; COMPLETE AND LASTING EXCLUSION OF DIRT AND FOREIGN MATTER by the use of tightly fitting, wearless, all-metal seals; SEALED FOR ANY POSITION, since the seals retain the lubricant regardless of shaft angle; EASY REGREASING AND INSPECTION WITHOUT DISMOUNTING, by means of refilling plug and removable seals.

Write for the Catalog. Submit your bearing problems for study and recommendation, without obligation. NORMA-HOFFMANN sales and service engineers, and distributors in principal cities stocking "CARTRIDGE" BEARINGS, are at your service.

"NORMA-HOFFMANN"

CARTRIDGE

BALL BEARING

PRECISION BALL, ROLLER and THRUST BEARINGS

NORMA-HOFFMANN BEARINGS CORP'N., STAMFORD, CONN., U.S.A. • FOUNDED 1911

TRI CLAD moves up!

NOW . . . .

TRI CLAD polyphase induction motors are available in integral-hp sizes through . . . 75hp

THREE "EXTRA PROTECTION" FEATURES GIVE EVERY TRI CLAD MOTOR . . . GREAT STRENGTH AND LONG LIFE

1 Extra Protection against Physical Damage

ARMORED CONSTRUCTION . . . SMOOTH CONTOURS . . . RIGID ALIGNMENT Strong, one-piece, cast-iron frame and cast end shields, with upper portion completely enclosed, protect vital motor parts from external blows, falling objects, or dripping liquids.

2 Extra Protection against Electrical Breakdown

"FORMEX" WINDINGS . . BONDED COIL UNITS Features for extra protection against moisture, oil, abrasion, and heat-shock.

3 Extra Protection against Wear and Tear

NEW BEARING DESIGN . . . NEW OPERATING SMOOTHNESS Sleeve bearings proportioned and grooved for protective lubrication under severe loads. Sleeve and ball bearings enclosed in strong, dust-tight housings.

a LARGER range of sizes! a WIDER scope of service!

The advanced design and triple-tough construction that won industry's enthusiastic acceptance almost overnight have now been extended to many larger motors in our a-c line.

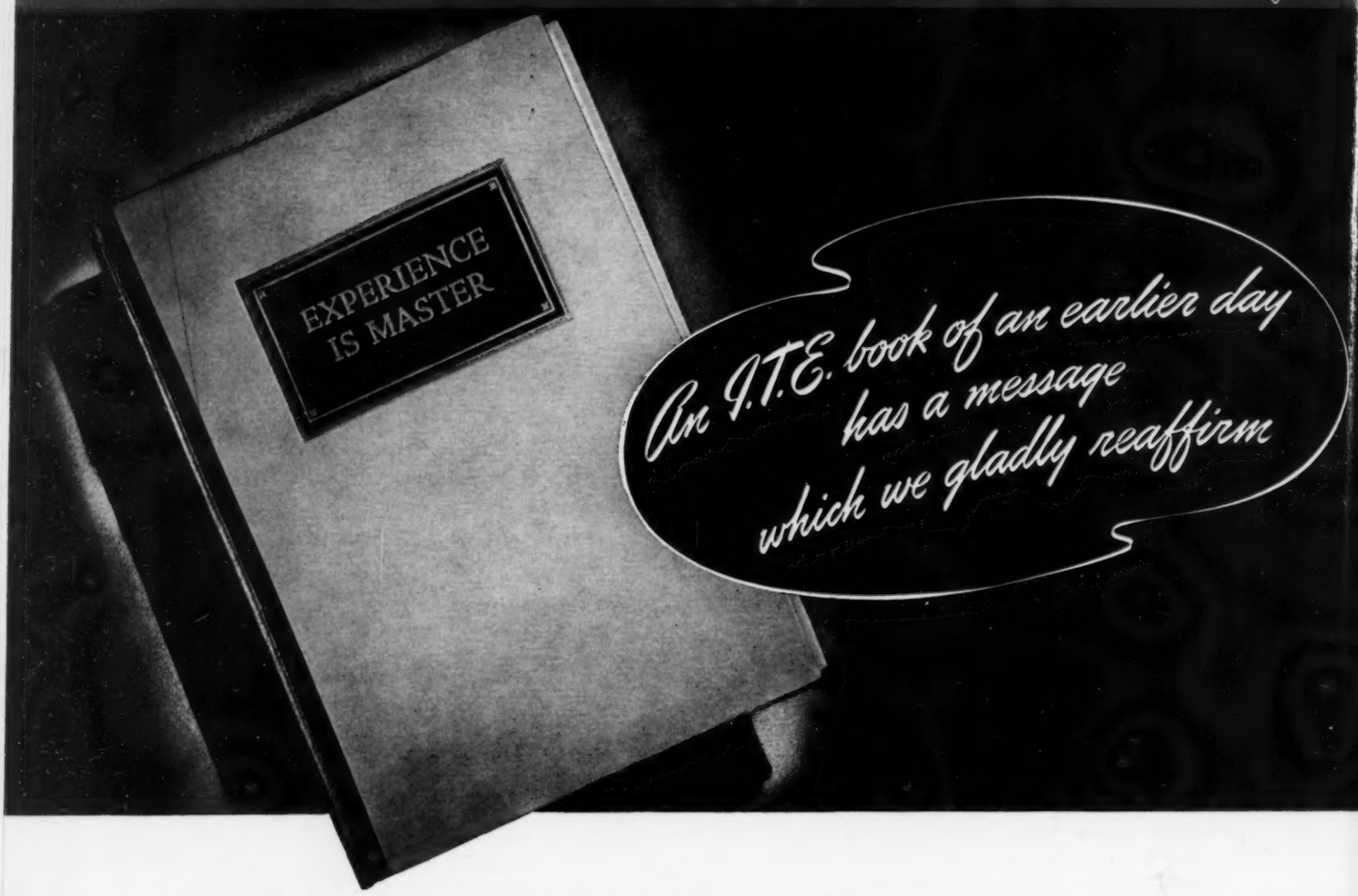
GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

General Electric and its employees are proud of the Navy award of Excellence made to its Erie Works for the manufacture of naval ordnance.

BUILT FOR PROTECTION FIRST . . . TO LAST!

GENERAL ELECTRIC

I-T-E Looks Ahead



Those who have known the I-T-E organization over many years realize how stable it has always been from the vital standpoint of personnel. Writing more than 15 years ago, Mr. A. Edward Newton, himself then an I-T-E veteran of nearly four decades, said, "Changes in our organization are of rare occurrence." He wrote to identify—by name, by picture and by work performed—the many men who, at that time, had spent more than 10 years with the company.

We refer to this book because the same message has important meaning now. The record of long individual service, which still stands except that it is greater, has bearing on our present strenuous occupations and on our future course.

At present, as in two previous periods of war, industry and government agencies find a large group of men at I-T-E who have concentrated years of effort in the single field of electrical protection. I-T-E switchgear designs and construction practices are accepted as the work of men who know their business. In time of emergency, experience, more than ever, is master.

The stability of the organization holds promise for the future. Knowledge is gained by continued searching. Need for new developments in the protective field are foreseen by daily contact, and provision is made for supplying new requirements. For a company whose men have devoted their working lives to one essential art, horizons expand.

★ ★ ★

Special note can well be made of the service of men in our field organization.

The I-T-E book of some years back says, "It takes years to make an I-T-E salesman." Even more time is required now than then, for I-T-E services have broadened. Applications of the I-T-E air-immersion principle have extended into a much wider range, and, whereas once we built circuit breakers only, our pioneering efforts have popularized complete, factory-assembled, steel enclosed switchgear.

It is possible that you are personally acquainted with at least one veteran member of our sales staff. He will continue to see you during the period when the factory is totally occupied with switchgear for war demands. With you, he will look ahead to new days, new problems and new solutions.

I-T-E

AIR SWITCHGEAR

IMMERSED IN AIR • ENCASED IN STEEL

Representatives In Principal Cities

CIRCUIT BREAKER CO., PHILADELPHIA, PA.